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THE NEW ANTHROPOGENY: TWENTY-FIVE STAGES OF VERTEBRATE EVOLUTION, FROM SILURIAN CHORDATE TO MAN[1]

By Professor WILLIAM K. GREGORY

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THE subject of anthropogeny, as it was developed at the hands of Ernst Haeckel, involved an attempt to read the earlier stages of prehuman evolution largely from the data supplied by human and comparative embryology. Thus its main postulate was the so-called "law of recapitulation." But the attacks of modern zoologists on this "law" seem to have led, in this country at least, to a loss of confidence in Haeckel's chief conclusions. In certain quarters there has sprung up a regular epidemic, which may be named *Haeckelophobia*.

Meanwhile the new anthropogeny has been gradually taking shape. But before speaking of its origins and tentative results to date, it might be well to note that a humble exponent of the new doctrine is liable to experience a slightly guilty feeling if he finds himself obliged to speak in any official gathering of his scientific brethren. For example, the brethren of the orthodox anthropologist sect are always piously busy, wielding their magic measuring wands and ringing the bells on their magic calculators, or thinking machines, while the poor anthropogenist stands idly by and must confess that he is not primarily bent on measuring or counting anything, but only in piecing together the broken story of the "big parade" that nature has staged across the ages.

Another contrast between the anthropogenist and

[1] Address of the vice-president and retiring chairman of Section H—Anthropology, American Association for the Advancement of Science, Atlantic City, December 29, 1932.

the orthodox anthropologist is that the regulars stand happily among the topmost branches of the family tree of man and count all its twigs, while the anthropogenist, like a silly ant, runs up and down the main branches and trunk and gropes blindly around the roots.

Moreover, up to the present time the new anthropogeny is operating to a considerable extent on a borrowed, or perhaps appropriated, capital of facts. And up to date it has found no way to repay the lenders.

For example, from historical geology the new anthropogeny appropriates the standard divisions of geologic time in which the drama of evolution has been played. But until relatively recent times geology could determine only the sequence of terrestrial events, without measuring their duration in years.

To physics, mineralogy and stratigraphy, the new anthropogeny now owes the "radium clock" of geologic time. If the readings of this clock give even a preliminary approach to the truth, as they seem indeed to do, then the events which the new anthropogeny attempts to discover and describe took place during a period of the general order of magnitude of five hundred million years.

From zoology and comparative anatomy the new anthropogeny has received the precious doctrine of the *"Êchelle des Êtres,"* or scale of beings, which was elaborated by the French naturalists of the eighteenth century, but which has since been almost abandoned and forgotten. Instead of throwing this doctrine on the junk-heap along with Euclidean geometry, the new anthropogeny finds that after being slightly revamped and fitted with a few new parts, the old apparatus still functions well; for it has led to a fuller recognition of the significance and importance of "living fossils," which have preserved in greater or less degree the successive grades of organization that were characteristic of many past ages. The study of the scale of beings has led also to the realization that if there were no "living fossils," that is, if every phyletic line had evolved at the same equal and constant rate, all the descendants of a common ancestral stock would now be indistinguishable throughout their anatomy. In other words, the very existence of comparative anatomy depends upon the fact that there is a more or less closely graded scale of beings, or rather, many scales of beings, leading not only toward man but toward every other highly specialized animal.

To paleontology, however, we owe the discovery of actual fossil skeletons that correspond more or less closely to the grades of organization inferred from the study of the scale of beings. Thus there is no longer any need of inventing hypothetical stages, as Haeckel did from doubtfully valid extensions of embryological processes, when the paleontological evidence is so unexpectedly adequate if viewed in the light of evidence from several different fields.

If the obligations of the new anthropogeny to all the previously named sciences are great, still greater is its dependence upon the science of vertebrate taxonomy; this branch of science endeavors to identify and follow the large and small branches of the vast tree of the vertebrates. We may be inclined to smile at first at the simplicity of Haeckel's picture of the tree of life, which might now be condemned as "monophyletic" and rejected in favor of a "polyphyletic" diagram with innumerable lines all running back to infinity. However, the cumulative experience of modern paleontologists and zoologists leads to the concept that while the tree of vertebrate life has a fairly large number of minor twigs which run back for long distances in geologic time, the number of major branches is quite limited and can be fairly well grasped during the lifetime of an ordinarily industrious student of fossil and recent vertebrates. But the supreme mistake would be to suppose that the branches have grown at equal rates, that is, that the "chronometer of evolution" runs at the same rate in all lines; it would be another mistake to infer that the branches never did run together because we have not yet located all the junctions. For the progress of vertebrate paleontology constantly leads to the discovery of new forms, yet in most cases the new forms represent branches that lie in between two or more branches already recorded.

Perhaps the most essential of all services rendered to the new anthropogeny by the science of phylogenetic taxonomy is the identification of branches that can be definitely excluded from what we choose to call the main line of ascent to man. Another service is the determination of the probable distance of a given branch from that main line.

Anthropogeny likewise borrows from chemistry, physics and physiology the very basic principle that man, like other organisms, is a sort of solar engine that runs by means of the energy stored up in plant and animal food. It follows that this potential energy forms a hidden prize of great worth, to obtain which all animal life struggles unceasingly. Hence the drama of terrestrial evolution is motivated by the complexly ramifying competition and strife for food and for reproductive mates; this principle operates as strongly in the latest stages of life as it did in the earliest.

We may start then with one of the most firmly grounded landmarks in the new anthropogeny, namely, that man belongs on the vertebrate tree of life, and that, while his present habitus is that of the human biped, his general heritage is that of a quadrupedal

vertebrate of the class of mammals and of the order of Primates. These general facts were well known to Huxley, Haeckel, Darwin, Lamarck, and even to a large extent to Linnaeus, but they are always being buried and forgotten under the details about which scientific men love to dispute. What was not known to the older naturalists, however, is the modern wealth of material that supplies us with a paleontological series representing the main successive structural stages in the long ascent from the jawless chordates of the Silurian age up to man.

At present we may distinguish about twenty-five structural stages from and including the oldest known pre-fishes up to modern man. It is not claimed that these stages lie exactly in the direct line of ascent but only that they are more or less near to it after the elimination of more specialized side branches.

Let us attempt to run over these stages very briefly with the lantern slides.

We may consider for a moment the general history of the locomotor apparatus, especially the skeleton. We start with the fact that the larger units of the vertebrate locomotor system are the W-shaped muscle flakes, or myomeres, on the side of the fish; the smaller units are the striped muscle fibers with their far smaller fibrillae, which run into the billions in a human body. The beginnings of all the complex motions of the human body are to be sought in the rhythmic contraction and relaxation of the W-shaped muscle flakes of the fish, and there are already on record many structurally intermediate stages between the simple muscles of the fish and the complex muscles of man. And it is sufficient to mention in passing that the human embryo agrees with that of the fish in that not only its axial muscles but also the segments of the backbone arise from segmentally arranged buds of mesoderm on either side of the embryonic notochord.

Stage 1. Pre-fishes (Ostracoderms) of Paleozoic times (Ordovician to Devonian).

For the purpose of this address we must leave out of account the disputed problem of the origin of the vertebrates and begin with a grade of organization that was already far nearer to that of man than to the one-celled starting-point. Thanks to the Danish scientific expeditions to Greenland, Norway and Spitzbergen, we now possess a surprisingly detailed fund of information regarding the general characters of the brain and cranial nerves and blood-vessels of these oldest known Chordates; these have recently been described in the beautiful monographs by Stensiö and Kiaer. Thus we now have a firm foundation of facts to replace conjecture. These pre-fishes, or ostracoderms, were bilaterally symmetrical, with a median axis, or notochord, moving by lateral undulations of the body, by contractions of W-shaped muscle segments. The head was of the complex vertebrate type, including a braincase that contained three pairs of main sense organs, corresponding to the olfactory, optic and otic capsules of higher vertebrates and arranged in a fore-and-aft series.

A continuous endoskeletal tissue, containing bone-cells in one order of ostracoderms, enclosed the three main pairs of sense organs and formed a trough for the brain and tunnels for the cranial nerves and blood-vessels. When these tunnels and this braincase became filled with mud, which subsequently became mineralized, there was left a record of the general anatomy of the nervous system which has endured for perhaps four hundred millions of years, down to our own time.

Beneath the braincase was a greatly expanded chamber containing the mouth cavity, the gill-pouches, the skeletal partitions between the gill-pouches and the ducts leading to and from the gill-openings and the exterior. This arrangement is closely paralleled in the larval stage of the existing lampreys. The same is true of the brain and cranial nerves. The neurologists and students of the classical problem of the vertebrate head-segments had long ago fixed upon the larval stage of the lamprey as standing nearest among existing forms to the archetypal vertebrates. Thanks to the labors of many investigators, we can now affirm that the ostracoderms as a class were the archetypal vertebrates from which were derived, on the one hand, the so-called jawless cyclostomes, or lampreys and hags, and on the other hand, the gnathostomes, or jaw-bearing vertebrates, comprising true fishes, amphibians, reptiles, birds and mammals (including man).

Stage 2. "Antiarchs" of Devonian age.

These strange-looking forms had the head and body enclosed in an armor of bony plates and propelled themselves by a pair of jointed appendages that remind us of the walking legs of crabs. They were probably quite far off the direct line leading to higher vertebrates, but the beautiful fossils from Scaumenac Bay, Quebec, described by the late Professor Patten and now by Stensiö, leave little doubt that these antiarchs had recently crossed the line separating the so-called jawless from the true jaw-bearing forms. For they had obviously acquired external jaw plates, homologous with those plates in the true fishes which were destined to give rise ultimately to our own upper and lower jaws; while, according to Stensiö, their external jaw plates could only have been supported internally by cartilaginous bars homologous with the true or inner jaws of adult sharks and of embryonic higher vertebrates.

Stage 3. "Pre-sharks" of Devonian age.

The earlier acanthodians may well be called "pre-sharks" because, although shark-like in general characters, they represent an older and more primitive type nearer to the line of ascent to higher vertebrates.

Externally the acanthodians give us a glimpse of an early stage in the evolution of paired limbs. They support the conclusions of Balfour, Dean and others that the paired fins are essentially the same as the median fins and that both arose as folds of skin and projections of the muscular body-wall that served originally as stabilizers and keels. Such fin-folds in the early stages had wide bases and limited mobility.

The pre-sharks had attained an early stage in the evolution of the gnathostomes, or jaw-bearing vertebrates, since they had inner or true jaws, in series with the gill-arches. In another early shark, *Cladoselache,* we see in this view of the under side of the head how closely the upper and lower jaw bars are in series with the gill-arches, from one pair of which the jaws were doubtless derived.

Stage 4. "Basal ganoid fish" (Palaeoniscoid), Old Red Sandstone (Devonian).

These earliest known forerunners of the modern bony fishes used to be called "osseous sharks" by the late Professor Bashford Dean, because they combine a generally shark-like body-form with the bony armor over the head and shoulder-girdle of the earlier typical fishes. This bony armor is composed of plates, each one of which has a definite name. Many of these plates, such as the frontals, the parietals and the surface bones of the upper and lower jaws, can be traced forward, as we shall presently see, from these very early fishes up through the amphibians, the earlier reptiles, the mammal-like reptiles, to the earlier mammals and thence through the lower primates to man. Other elements of the fish skull, such as the bones of the opercular series that covered the gill-chamber, disappeared when fish turned into amphibians.

These earlier true fishes also exhibit the fins in successive stages of development. The anal fin is still just like the dorsal fin, with an extended base supported by a regular series of little bony rods. The pelvic fins show an early stage in the crowding of the basal pieces, especially at the front end. The pectoral fin has already attained the stage of a broad paddle with a crowded base.

This sequence is still clearly seen in the fins of the spoon-bill sturgeons, or paddle-fishes, which are the otherwise specialized descendants of the earlier ganoids. Here we see three stages in the evolution of the mobile pectoral paddles, as figured by Dr. Tate Regan, of the British Museum of Natural History.

Stage 5. "Lobe-finned" fishes, of Upper Devonian and Lower Carboniferous ages.

The tendency toward the evolution of freely turning paddles, presumably out of fin-folds, reaches a climax among the lobe-finned fishes of late Paleozoic times. In the tassel-finned branch of these forms the paddles grow at the distal end and give rise to a string of joints with slender rods on each side. But in the "fan-finned" branch the paddles spread out like the sticks of a fan, and the bony rods that support them seem destined to give rise to the skeleton of the arm and hand of higher vertebrates. This fan-shaped stage is well illustrated in an Upper Devonian form to which the geologist James Hall in 1843 gave the appropriate name *Sauripterus*—"lizard-fin." We shall see a little later how such a paddle might give rise to the cheiropterygium, or five-rayed hand, of a higher vertebrate.

Before going on to the next higher stage we must pause for a moment in order to rule out the dipnoans, or lung-fishes, from the line of ascent to the higher vertebrates and to expose their true place on a side branch further away from the main line than that which they occupy in the genealogical trees figured by Haeckel and by his modern follower, Professor Naef. The dipnoan lung-fishes are excluded from the main line by three sets of characters: first, they belong in a division with feather-shaped, or leaf-shaped, paddles, in which the many-jointed central axis is predominant; secondly, their dentition is specialized in a very peculiar way, which leads to nothing but that of their modern descendants and is widely different from the dentition of the earliest amphibians. Thirdly, the lung-fishes are excluded from ancestry to the higher forms by the highly peculiar specialization of the extremely massive inner skull, and by the bizarre pattern of the many small plates covering the braincase.

On the other hand, the ancient lobe-finned fishes present nearly ideal conditions, not only of the paddles, but also of the dentition and skull patterns, to favor their claim to be on or near the main line of ascent to the four-footed, air-breathing vertebrates.

The living *Polypterus* of Africa is a justly famous survivor of the most ancient ganoids. From whichever of the two oldest orders of ganoids he may have been derived, he does show us how readily a lobe-finned paddle may be directed downward on either side of the body in a position to assist in wriggling on the mud.

Stage 6. Basal Amphibian. Upper Devonian and Lower Carboniferous.

Even the modern amphibians, including the frogs, newts and salamanders, retain so many essentially

fish-like characters, especially in their larval stages, and in the general pattern of the cranial and spinal nerves, that zoologists have never had any reason to doubt that amphibians have been derived from ancient air-breathing fishes of some sort.

Thanks to the recent labors of Bryant, Watson, Stensiö and others, on the fossil lobe-finned fishes, and to those of Watson on the Lower Carboniferous amphibians of Great Britain, the gap in our records between fishes and amphibians is being measurably lessened.

Indeed, it may now be said to be highly probable that although no known genus of lobe-finned fish was the immediate ancestor of the amphibians, yet the group as a whole has the characters to be expected in the descendants of an earlier common stock that gave rise, on the left, to the lung-fishes, near the center, to the known lobe-fins, and on the right, to the earliest tetrapods or amphibians.

Since the last sentence was written I have received the latest report of the Danish Geological Survey of Greenland, containing a monograph by G. Säve-Söderbergh entitled "Preliminary Note on Devonian Stegocephalians from East Greenland." These oldest known amphibians, which were discovered in 1931, aroused a great deal of interest in the American press a short time ago under the name of "four-legged fish." The present report fully justifies the expectation that when amphibians of Devonian age became known they would be decidedly nearer to the lobe-finned fishes than were the already known amphibians of the Lower Carboniferous. This now proves to be the case in the patterns of the skull top and palate as figured from beautifully preserved material.

The breathing of atmospheric air had already been acquired by several groups of fishes of the ancient coal swamps, as it has by several unrelated modern fishes. If we may judge from modern conditions, an oxygen-secreting pouch long served to tide the fish over periods of drought, and possibly the stout fan-shaped paddles of the lobe-fins may have assisted them in wriggling from one pool to another.

The greatest advance made by the earliest known amphibians over their fish ancestors is to be seen in their paired limbs. For each limb is now sharply angulated at the elbow and at the wrist, the basal supports of the bony rays have been crowded together so that they converge toward the postaxial arm-bone, while five of the paddle-rays have become modified to serve as fingers and the outer fin-rays have disappeared, leaving only the nails as a trace of their former existence.

As a result of studies in several fields, Gregory, Miner and Noble have attempted to visualize a possible intermediate stage between a fan-shaped lobe-fin of the *Sauripterus* type and the known pattern of the fore limb in a primitive amphibian.

When, however, we compare the skulls and jaws of the lobe-fins with those of the earliest amphibians, we have no difficulty in identifying homologous elements, or in accounting for those which are lacking in the amphibians.

When breathing by the air-sac finally superseded breathing by the gills, in the adult stage, it is not surprising that the opercular bones, which play an important part in branchial respiration, should have failed to ossify, leaving only a dermal flap. The region of the otic notch in Amphibia corresponds closely to that of the opercular flap in fishes.

As in many other stages of vertebrate ascent, we learn much from the highly specialized descendants of to-day, which in this case are the frogs, toads, salamanders, etc. Their skulls represent fenestrated and depauperized derivatives of the ancient amphibian type.

Stage 7. The Stem Reptiles (Cotylosaurs), Upper Carboniferous and Permian.

It used to be supposed that there was a great gap between the Amphibia and the reptiles, the former being classified with the fishes as Ichthyopsida, the latter with the birds and mammals as Amniota. But thanks to the labors of the late Professor Samuel W. Williston and others, we now know certain fossil forms that break down the old distinctions between amphibians and reptiles. It was said by the elder Huxley, for example, that the amphibians had paired condyles at the back of the occiput, while the reptiles had but one median condyle. It is now known that the primitive amphibians had tripartite condyles, from which were evolved, on the one hand, the double condyles of the typical amphibians and, on the other hand, the ball-like median condyle of modern reptiles and birds.

One of these early reptiles, *Seymouria*, is so nearly on the borderline between amphibians and reptiles that one set of his skull characters has been used to classify him as an amphibian, while other skull characters, together with the detailed construction of his vertebral column, justify his claim to be one of the stem reptiles.

In short, the most conspicuous advance among the reptiles was the elimination of the fish-like or aquatic stage of individual development. By enclosing an artificial watery environment within a water-tight egg the reptiles hit upon a "basic patent" which enabled them to invade the uplands and eventually to conquer almost the whole earth.

The earliest reptiles retained generalized 5-rayed hands and feet, and this constitutes one of their many

claims to be on or near the "main line" of ascent to man. The opposite course of digital reduction has been followed by most of the descendants of the ancient reptiles. It has invariably carried them away from the "main line" of ascent.

Stage 8. The Captorhinids, progressive cotylosaurs. Permian.

In the ancient "lobe-finned" ganoids the entire surface of the head was enclosed in a shiny armor of surface plates with openings only for the paired nostrils, the median pineal eye, the paired eyes. The outer jaws were merely the bony plates covering the inner, or gill-arch, jaws. The upper jaw plates were in series with the bony mask covering the head, the lower jaw plates covered the primary, or gill-arch, jaws. The jaw muscles were hidden under the shining facial mask. All this was equally true of the oldest amphibians and reptiles, except that the shiny surface of the bony skull plates was lost just before the amphibian stage.

In the captorhinids, which were rather progressive stem reptiles, the same conditions obtained, but these enterprising little forms had, so to speak, patented what we may call a "four-way palate brace" and were also using the oldest recorded orthodontic appliance, the "descending pterygoid flange," which kept the lower jaw in vertical alignment. Lack of time forbids further references to these devices except for the statement that they seem to be prerequisites for the development of the peculiar type of palate that appeared in the mammal-like reptiles.

Stage 9. The Texas Theromorphs, of Permian times.

As noted above, the jaw muscles of primitive vertebrates were covered externally by a shell or bone, forming the so-called "unperforated temporal roof." While this arrangement may have been advantageous by reason of the protection it afforded to the jaw muscles, it may also have had its inherent disadvantages, such as cramping the free expansion of the jaw muscles. But the Texas theromorphs hit upon the device of "fenestrating" by absorbing the central area of the temporal shell while strengthening its periphery. After this, nothing could or did stop the advance of the jaw muscles until the completely mammalian type of cheek arch had been reached. This was one of the reasons why Professor Cope classified these Texas Permian forms as Theromorpha, or mammal-like reptiles, and regarded them as ancestral to the mammals. The big ones are obviously too specialized in having a chevaux-de-frise of spines on top of the backbone, but the smaller ones, such as Williston's *Mycterosaurus,* avoided these specializations.

Stage 10. The Earlier Mammal-like Reptiles, of the Permian of South Africa and Russia.

South Africa is justly famous for its diamond mines, but from the view-point of anthropogeny its extinct mammal-like reptiles are of far greater significance. Even the earlier reptiles of the Karroo series had already progressed far on the long evolutionary road toward the mammalian grade of organization. For, while their own forerunners had been clumsy beasts, crawling with sharply bent elbows and knees, the South African theromorphs had begun to lift the body off the ground by bringing the fore and hind feet under the body. The skeleton, in fact, abounds in indications of progressively heightened activity associated with predatory habits. The skull was beginning to approach the mammalian grade, in the differentiation of the dentition into incisors, canines and cheek teeth, in the presence of a temporal opening and cheek arch of mammalian type, and in other features.

Stage 11. The Cynodonts or Pro-mammals (Triassic of South Africa and Russia).

The South African cynodonts advanced so far toward the mammals that they ought to have been called pro-mammals, and they are only technically still within the upper limits of the reptilian class. For instance, the skeleton is now well fitted for running, while the skull abounds in new advanced features directly foreshadowing the mammalian grade. The skull of the smaller cynodonts is strikingly like that of a primitive mammal in general appearance, arrangement of bones of upper jaw and nasal region of cheek bar, fossa for jaw muscles, etc., etc. That these cynodonts stand in between primitive reptiles and typical mammals is shown in almost every feature of their skeletons.

The lower jaw also was very progressive, but their official status as reptiles was validated by the retention of the old "reptilian joint" beneath the new or "mammalian joint."

The secondary palate was approaching that in mammals and stands between the primitive reptilian and the typical mammalian conditions.

The living relatives of the cynodonts are the mammals, including ourselves.

Stage 12. Ictidosaurians, Upper Triassic of South Africa.

These highly progressive derivatives of the pro-mammals (recently described by Robert Broom from two skulls) were on the borderline between reptiles and mammals. They practically break down the distinction between reptiles and mammals and show the absurdity of the statement that there are "no links

between classes." They possessed the new joint between the mandible and the temporal bone that is characteristic of the mammals, but they also retain the old reptilian joint between the quadrate bone and the articular bone of the mandible.

Possible survivors or relatives of Upper Triassic mammal-like reptiles may be seen in

Stage 13. The Duckbill Platypus and the Spiny Anteater of Australia.

Both these forms lay large reptilian eggs, have reptile-like oviducts and many reptilian features in skull and skeleton, also a relatively primitive brain. They represent an early stage in the evolution of mammalian characters, especially those that tend to maintain a higher, more stable body temperature and more sustained activity. These qualities have helped mammals to conquer the world and drive out the reptiles.

Stage 14. Pretrituberculate, Jurassic mammals.

There was once a dogma that "no mammals are found in Jurassic rocks," and when one was found there, some denied that it was a mammal, others that the rocks were Jurassic. But Cuvier pronounced it "the jaw of a little opossum," a nearly correct allocation. Three orders, numerous genera and species of Mesozoic mammals have been described from the Jurassic of England and Wyoming, but mostly from broken jaws and teeth.

The teeth represent several stages of evolution toward primitive mammalian types. The skull in general had advanced beyond mammal-like reptiles in the direction of the most primitive marsupials. In the more advanced members the teeth were of primitive tritubercular type, ancestral to those of later mammals, including man.

Stage 15. Cretaceous Opossum-like Marsupials.

Huxley, Dollo and later students have emphasized the extremely primitive character of existing American opossums, our oldest and most precious "living fossil."

Unfortunately, most Americans appreciate the opossum more for those qualities which have earned for him the title of "African turkey." It rather pains me to hear of great statesmen taking a holiday down South to hunt these poor animals to eat, when they ought to be securing them for the museums of the future or laboring to establish opossum sanctuaries. The opossum has an American ancestry which would make even the longest known human genealogy look like a last year's birth record from Ellis Island. For Barnum Brown, our curator of Fossil Reptiles, found in rocks of Upper Cretaceous Age in Alberta a fossilized skull of an early member of the opossum family embedded underneath a dinosaur skull. Its estimated age is about eighty to one hundred millions of years.

The opossum skeleton is highly instructive in many ways; *e.g.*, it shows incipient adaptations to tree-living habits, the use of the pectoral limbs as hands and of the hind feet for grasping. While not in the direct line to higher mammals, it preserves many characters which we may confidently look for in the direct ancestors of the Primates.

Stage 16. Cretaceous Insectivorous Placentals of Mongolia.

One of the greatest prizes of Dr. Andrews' expedition to Mongolia, discovered by Dr. Granger. Huxley, Osborn and others had predicted that ancestors of the higher or placental mammals would be found to be Mesozoic insectivores. These little forms are judged to be placentals, through the close resemblances of their skulls and teeth to those of existing insectivores. Uniting characters of the earliest insectivores and carnivores, they show an ideally primitive stage in tritubercular upper molars and give long-looked-for paleontological proof that the primitive cusp was not on the inner side, as believed by Cope and Osborn, but was located on the main cusp, homologous with the main tip of the premolars.

The surviving relatives of the Cretaceous insectivores are the Centetid insectivores of Madagascar.

Stage 17. Primitive Tree-shrews (?Upper Cretaceous to Lower Eocene).

Somewhere in late Cretaceous times a group of small placental insectivores took to climbing up trees, with momentous consequences. For here they gradually acquired those primary arboreal characters which, as there is much evidence to conclude, were deeply stamped into the anatomy and ways of life of our own remote ancestors.

The tree-shrews, however, took only the initial steps; their skeleton retained much of the generalized mammalian type; but while the hands and feet retained claws, initial stages in the evolution of the nails are seen in late members of the group (from the Tertiary of Mongolia).

The existing tree-shrews suggest ordinary insectivores in their large muzzle, but their skulls and teeth approach those of lemurs in certain important characters. In fact, some authorities want to classify them with the lemurs, but as they were a separate family far back in Eocene times, they may be treated as pre-Primates.

Stage 18. The earliest true Primates (Eocene).

There is one fraternal order to which all Americans belong by right of birth, though few are willing to

admit it, that is, the Order of Primates. This ancient and honorable order has an antiquity vastly exceeding even the claims of any that hold conventions in the big hotels; the bones of its founders have been discovered in the Bridger formation of Wyoming—their estimated age, about fifty millions of years. This most important skeleton I had the pleasure of naming in honor of the president of the American Museum of Natural History, Henry Fairfield Osborn.

The conspicuous characters are: While retaining five digits, it has grasping hands and feet fitted for climbing; the skull is progressive in its fairly large orbits; the brain is essentially lemur-like but lower and smaller; the dentition is very generalized for a primate; the dental formula is $I\frac{2}{2}C\frac{1}{1}P\frac{4}{4}M\frac{3}{3}$. Thus there were forty teeth in the adult, while in anthropoid apes and man the number has sunk to thirty-two.

Some paleontologists, including Drs. Wortman and Gidley, saw in *Notharctus* an ancestor of the South American monkeys, but to me it is too generalized to be classified with the South American monkeys. It is rather closely related to the Adapidae of Europe, which in turn are probably near the stem of the Madagascar lemuroids. Thus *Notharctus* may not be in direct line of ascent to man, but it is most instructive in showing how deeply arboreal characters had been impressed on the Primates by the Lower Eocene, fifty million years ago. Many lines of evidence support the view that the Primates as an order were fundamentally arboreal and that later semi-terrestrial types, like the baboon, or fully terrestrial types, like man, were all secondary.

Stage 19. The Tarsioids (Eocene).

The active arboreal life of the Primates requires a high development of sight. Hence the Primates were primarily big-eyed forms. This tendency early ran to extremes in the tarsioids, which Dr. Wood Jones regards as nearer than any other known forms to remote ancestors of man. But while it is not necessary to accept the tarsioids as *direct* ancestors, they show certain advances in the optical organs which the ancestors of man must have passed through. Excessive specialization, however, even in the Eocene *Anaptomorphus,* has led to extreme squeezing of the interorbital region and extreme diminution of the nasal chamber. The tarsioids were also early overspecialized in the hopping adaptations of their feet; this again rules them out of the direct line. Nevertheless, even in the modern *Tarsius* their brain and soft anatomy are pretty primitive and in many respects they bridge the gap between lemurs and monkeys; not impossibly they stand rather near to the unknown direct line leading to apes and man, though their relationship to man, in the judgment of most students of the subject, is not nearly as close as is the relationship of the apes to man.

Stage 20. The separation into New World and Old World series.

The question of the precise degree of relationship between the New World and the Old World monkeys has been considered from many angles, but there is no unanimity of opinion. In spite of certain common characters of the brain, placenta, etc., it seems possible that the New World monkeys were derived from some as yet unknown family other than that which gave rise to the Old World series, as maintained by Stehlin. They are widely separated in space and time and widely differentiated in many anatomical characters; *e.g.,* in details of skull and dentition.

The Old World monkeys are distinguished from the New World series not only by the narrow nostrils ("Catarrhinae") but also by the dental formula, already reduced to the same figures as in man and apes, namely, $I\frac{2}{2}C\frac{1}{1}P\frac{2}{2}M\frac{3}{3}$.

Dr. Wood Jones has referred to certain skull characters in which Old World monkeys appear to be too specialized to give rise to man. The same is true of their molar teeth. Nevertheless, the skeleton as a whole is far nearer the ancient Primate type in that the Old World monkeys are still mostly pronograde, *i.e.,* they do not practice brachiation, or arm-swinging, as much as do the anthropoids. Their hands and feet also are much more primitive, and the same is true of their brains.

Stage 21. The founding of the Anthropoid dynasty.

From the Lower Oligocene formation of upper Egypt, Professor Max Schlosser, of Munich, described two priceless little fossil jaws, illustrating two stages of evolution of the Primates. The smaller one, *Parapithecus,* already a living fossil in its own time forty million years ago, was apparently a hold-over from the tarsioids of the Eocene. At least it agreed with them in having a very short jaw, very wide at the back as seen from above, implying a much expanded braincase, and pointed in front. The teeth combine some characters of tarsioids with others of the anthropoid-human series.

The second stage was definitely a small anthropoid ape but of immense antiquity and primitiveness. It was named by its discoverer *Propliopithecus,* as a forerunner of *Pliopithecus,* the ancestor of the gibbon, but much more primitive than the gibbons in jaw and teeth. It has advanced beyond the tarsioid stage in widening of the front end, implying widening of tongue (embryonic jaw moulded by tongue). Dental formula: $I_2C_1P_2M_3$, as in anthropoid apes and man.

Molar teeth of primitive anthropoid type with five main cusps. It has been regarded by an eminent anthropologist (Sergi) as an ideal ancestor of man, but it might be a near ancestor of the entire ape-man series in characters of the lower jaw and dentition.

The modern gibbon, as a descendant of *Propliopithecus,* is a somewhat overspecialized side branch with excessively long arms and legs and saber-like upper canine tusks. Nevertheless, in many ways it represents a transitional stage between monkeys and apes. It retains the last traces of ischial callosities. Several characters of the skull and skeleton, but especially the molar teeth, definitely and surely classify the gibbon as an ape, not a monkey. The Johns Hopkins University school of anatomists concludes that the human line came off far down the anthropoid stem, a little above the level of the origin of the gibbon. I feel that there are too many strong bonds between man and the higher anthropoids to make the pro-gibbon ancestry of man probable, but all are agreed that man has come off from the anthropoid stock either earlier or later.

The gibbon skeleton is thoroughly adapted for brachiating. This is generally defined as "arm-swinging," but if we watch living gibbons we see that the legs play a very important part in leaping. The habit of brachiation has brought the backbone into a vertical position at right angles to its primitive horizontal position, and some authorities believe that brachiation is a prerequisite to human evolution. We may readily concede, however, that the gibbon is now in an advanced overspecialized phase of brachiation which need not be imputed to the early Tertiary anthropoids.

Stage 22. The Miocene Anthropoids.

During the Miocene epoch the anthropoid group was represented by many species found as fossil jaws and teeth in France, Germany, the Vienna basin, Spain, northern Egypt and India; hence there was a broad zone extending across Europe and India with later offshoots in tropical Africa, South Africa, China, and southeastern Asia. This wide-ranging group was highly variable in size and in details of the dentition. They are known to date only from scattered jaws, one humerus and one femur. An eminent mammalogist demands fossil ape skeletons that include well-preserved hands, feet, pelves, etc., before admitting the evidence of fossil apes to his private court of judgment; but fossil apes do not come to us in that form. Nevertheless, these jaws and teeth of fossil apes are of extraordinary value, for they reveal both the wide plasticity and wide geographic distribution of the anthropoid stock. Barnum Brown discovered in India several important jaws shown in composite form in the figure. The jaw is deep and massive; there are thirty-two teeth; the canines are prominent, the opposite tooth rows are parallel as in apes.

The cheek teeth are of great interest because the pattern appears to be archetypal to that of man. The lower molars have three cusps on the outer side, two on the inner side, with elaborate "*Dryopithecus* pattern" of grooves, also a "fovea anterior" and "fovea posterior." Exactly this combination is found in primitive human jaws along with new and distinctly human characters. The characters of the premolars and molars support the view that man is an offshoot from some member of the *Dryopithecus* stock and with closer relationships to the African anthropoids than to the gibbon and the orang. The reduction of the canine in man is quite secondary, as supported by the extensive researches of Remane.

Dr. Gerrit S. Miller, Jr. (as quoted in a recent note in SCIENCE) objects that men and anthropoids are different kinds of giants, as compared with Primates of average size, and that there is no fossil-proved precedent for one kind of giant's turning into a different kind of giant. He therefore classes the derivation of man from a Tertiary anthropoid stock as "an alluring speculation," choosing to ignore the hundreds of anatomical characters that tie man with the anthropoids in a single systematic group. But there are giants and giants. The crown of the third lower molar of *Dryopithecus fontani* measures about 11 by 9.2 millimeters in anteroposterior and transverse diameters, respectively, while that of *Dryopithecus giganteus* measures 19 by 15.3 millimeters.[2] This wide range of variability in size in the older group does not seem to favor Dr. Miller's assumption of unalterable, fixed divergences between the two.

The conclusion that man is closer to the *Dryopithecus* stock than to the gibbons seems also to be opposed by my colleagues in Johns Hopkins University, and although I am prepared to defend it in detail, I do not regard it as essential for the present purpose, which is merely to reaffirm the conclusion that man in much the greater part of his characters is nearer to the anthropoid apes than to the more primitive Primates.

Stage 23. The extinct South African Anthropoid (Australopithecus)

This amazingly well-preserved fossil was described by Professor Raymond Dart, of the University of the Witwatersrand, South Africa, in 1925. It was found in a fissure deposit near Taungs, on the eastern edge of the Kalahari desert. Its geological age is

[2] William K. Gregory and Milo Hellman, Anthropological Papers of the American Museum of Natural History, Vol. xxviii, Part I, 1926, p. 74.

not precisely established but, according to Dr. Robert Broom, two species of fossil baboons and an extinct species of *Hyrax* have been found in the same level. He therefore considers the age of *Australopithecus* to be Pliocene. But whether the age be Pliocene, Pleistocene or Recent, this skull is of exceptional interest. Extremes of judgment about the skull are first, that of Professor Dart, who regards it as the representative of a new family "Homosimiidae" widely removed from the African anthropoids; at the opposite extreme is the conclusion of Dr. Wolfgang Abel, of Vienna, who regards it as closely related to the gorilla and having nothing whatever to do with human ascent. Dr. Milo Hellman and I, who have studied the excellent casts of the upper and lower teeth, conclude that while it is a young anthropoid, related to the existing African genera, yet its deciduous canines and molars and its first permanent molars are, on the whole, unequivocally more man-like than those of the existing young gorilla and chimpanzee; while its permanent molars are definitely not those of *Gorilla* but present beautiful examples of a modified *Dryopithecus* pattern akin to those of the Ehringsdorf and Mousterian fossil human stage. In short, while we do not yet know the form of the adult skull of *Australopithecus,* it is safe to affirm that this child skull is strikingly "prehuman" in the general appearance of its cranium and facial skeleton and that it tends to lessen the phylogenetic gap between man and the existing African anthropoids.

Stage 24. Man appears.

With regard to the fossil human remains known as *Pithecanthropus,* found in Java, and *Eoanthropus,* found in England, scientific controversies have raged to such an extent that the eminent mammalogist already cited has urged that these names be, so to speak, wiped off the scientific slate until they are documented by better material. Fortunately, we need not for the moment at least contest this quite arbitrary ruling, for new and unimpeachable material of early man has been discovered near Peking and admirably described by Dr. Davidson Black. One of the Peking skulls was only little more advanced than that of *Pithecanthropus,* while the second was slightly further advanced toward the Neanderthal type. But according to the masterly field investigations of Teilhard de Chardin, the Peking human remains are contemporaneous with an extensive mammalian fauna that retains many elements characteristic of the Pliocene age, along with others indicating Lower Pleistocene age. Moreover, the Peking horizons belong in the Red Earth series, which are older than the thick loess deposits of Pleistocene age. Hence the Peking man, according to Chardin, is far older than the typical Neanderthals of the late Pleistocene of Europe, while its skull-contours, as figured by Black, are all lower and more primitive.

Without entering into controversial questions as to the geological age of the Piltdown and *Pithecanthropus* remains, it seems highly probable that the ancestors of *Sinanthropus* in late Tertiary times would have been properly classifiable as men rather than as apes. Time after time the Pliocene representatives of modern mammalian families have been shown to be almost modern in the appearance of their teeth, skulls and feet.

But here, as always, we must avoid the serious logical error of assuming for man the low average rate of evolution that obtained in non-Primate mammals. Moreover, the Lower Pleistocene *Sinanthropus* stands so far below *Homo sapiens* in cranial capacity that a backward prolongation of the curve at the same rate would presumably bring down the figures to the horizon of the anthropoids at no very distant geological date. Finally, according to the eminent geologist, Professor Schuchert, of Yale University, who has given prolonged consideration to this problem, the duration of the Pliocene epoch is many times greater than that of the Pleistocene. At present I know of no single item of objective evidence for the view that the human family began to diverge from that of the anthropoid apes as far back as Lower Oligocene or Upper Eocene times, forty or fifty million years ago; although in all fairness it should be noted that many other families of mammals did part company with each other at even earlier dates. But upon another occasion I was at some pains to demonstrate that, considering only the molar teeth and the feet, the structural differences between two families, the tapirs and the horses, that are known to have diverged in Lower Eocene times, are now far greater than the differences in the patterns of the molar teeth and of the feet respectively between modern men and modern apes.

But at whatever period, early or late, the human family may have begun to diverge from that of the anthropoid apes, it appears to be virtually proved by hundreds of separate items of evidence that men and apes are the divergent offshoots of a common stock, the existence of which, though not the period, is sufficiently documented by the huge mass of evidence already at hand. But it is not to be expected that this still growing mass of evidence for man's evolution from the lower animals will quiet the loud demands of anti-evolutionists for "objective evidence."

Stage 25. Homo sapiens, the big-brained devastator.

The existing anthropoids have a veritable passion for tearing things apart; but in point of destructive-

ness they are bungling amateurs, compared with their big-brained relative *Homo sapiens*. In him, by a series of conditioned responses, destructiveness within the family and tribal limits was restrained, but when enemies were to be ravaged and pillaged it was given full rein. For untold millions of years the line of vertebrates that led toward man were unblushing thieves and robbers; even now, the human face beneath its smiling mask carries the old mammalian trap set with sharp teeth. Such being the case, it is no wonder that we suffer from grafters, racketeers and gunmen. The wonder is not that so many of us find ourselves in prison but that any of us ever learned to keep out.

However, as soon as apes began to go in families and hordes, the counter principles of more or less unselfish interest in others began to operate; even in the lowest of existing social organizations there seems to be more or less clear proof of the unselfishness of mothers, the devotion of fathers, the generosity and disinterestedness of friends. Such a patchwork of good and evil is *Homo sapiens!*

But it does not seem that the pessimists are necessarily right. As Dr. Clark Wissler has pointed out, particular cultures may disappear, but culture itself goes on. And in view of the nearly world-wide distribution of *Homo sapiens* it would be hard to imagine any purely terrestrial epidemic or insect scourge that could wipe him out over his entire range.

Finally, man, in respect to the high development of his brain and other characters, may well represent an early stage in the differentiation of a virtually new class of vertebrates. The paleontological record shows repeatedly that, in the long past, once a new class gets started it runs for hundreds of millions of years. So that, taking the available evidence into consideration, it seems safe to predict that *Homo sapiens* will eventually muddle through this depression and survive to endure others in the future.

SUMMARY

The "Anthropogenie" of Ernest Haeckel, a pioneer work of great difficulty, depended to a considerable extent upon the so-called biogenetic law. Since the validity of this law has been attacked by several modern zoologists, public confidence in Haeckel's conclusions seems to have been undermined, at least in certain parts of the country. The "new anthropogeny" has grown chiefly out of the progress of paleontology, comparative anatomy, phylogenetic taxonomy and the comparison of the *échelle des êtres* among recent and fossil series. It seems that we are now in a position to substitute for the more or less hypothetical stages postulated by Haeckel a new and independently discovered series representing groups that depart the least from a continuous ascent. This, of course, involves the exclusion of all other groups which show more than the least observed differences from the more nearly continuous series.

For example, Haeckel relied upon the lung-fishes (Dipnoi) to bridge the gap between earlier fishes and the Amphibia. The Paleozoic Dipnoi are now seen to have been further from the "line of least change" than were their contemporaries, the lobe-finned ganoids (Crossopterygii), which possess in an earlier form a great many of the skeletal characters that were inherited by the Amphibia. It is concluded by Watson and others that the "lobe-fins" were descendants of an earlier group, which also gave rise in one direction to the Dipnoi, in the other to the Amphibia.

The new anthropogeny, as far as developed to date, submits the following series, subject, of course, to correction by further discovery:

(1) *Pre-fish* (*ostracoderm*) of Ordovician, Silurian and Devonian age. Paired sense organs, brain and cranial nerves, all fundamentally identical with those of the larval lamprey. "Gill-arch" jaws not developed.

(2) *Antiarch.* "Gill-arch" jaws incipient, outer jaw bones present. Known forms: *Pterichthys, Bothriolepis,* etc.; probably well off the main line except in characters noted.

(3) *Pre-shark* (*acanthodian*). Devonian. "Gill-arch" jaws (in series with gill-arches) fully developed. Paired fins arising from stabilizing fin-folds.

(4) *Basal ganoid fish.* Devonian. Enamel-covered bony mask over face and gill-chamber. Inner (primary) and outer jaw-parts complete. Anal, pelvic and pectoral fins showing progressive evolution from fin-fold to paddle type. Pectoral girdle complex (surface and deep elements). Near line of ascent to typical true fishes.

(5) *Lobe-finned ganoid.* Devonian and Lower Carboniferous. Paired fins with shortened bases and crowded, fan-like skeleton. Teeth labyrinthodont, primary jaws covered with bony plates. Many bones of skull-roof homologous with those in later vertebrates. Cleithrum predominant in pectoral girdle.

(6) *Basal amphibian.* Lower Carboniferous. Paired limbs with five-rayed digits. Vertebrae cut up, large intercentra. Pectoral girdle at first retained cleithrum from fish stage. Teeth labyrinthodont. Opercular bones absent. Skull patterns archetypal to all later tetrapods. Occipital condyle tripartite. Aquatic (tadpole) mode of development.

(7) *Stem reptile.* Upper Carboniferous. Presumed elimination of tadpole stage. Vertebrae simplified, intercentra small. Occipital condyle tripartite to single and median. Cleithrum reduced. Limbs of crawling type.

(8) *Progressive cotylosaur* (*captorhinid*). Permian. Retaining primitive shell of bone over temporal muscles. "Four-way palate arch" developed from primary upper jaw. Skeleton lizard-like.

(9) *Texas theromorph.* Permian. Temporal roof fenestrated by jaw muscle, leaving zygomatic arch of pre-mammalian type.

(10) *Earlier mammal-like reptile.* Permian of South Africa and Russia. Limbs adapted for running. Dentition carnivorous, with incisors, canines and cheek teeth. Temporal region of pre-mammalian type. Dentary bone of lower jaw with obliquely ascending ramus. Occipital condyle single.

(11) *Cynodont or pro-mammal.* Triassic of South Africa. Skull sub-mammalian in: zygomatic arch, secondary palate, differentiated dentition, double occipital condyle, etc. Lower jaw with increasing ascending ramus finally approaching squamosal bone. Jaw bones behind dentary reduced. Quadrate small. Skeleton of sub-mammalian running type.

(12) *Ictidosaurian, near-mammal.* Upper Triassic, South Africa. Skull almost mammalian. Lower jaw with large, nearly vertical, ascending ramus of dentary and much reduced jaw bones behind dentary.

(13) *Prototherian mammal.* Known chiefly from recent Duckbill (*Ornithorhynchus*) and *Echidna* of Australia. Retaining semi-reptilian type of eggs and oviducts. Primitive skeletal features, especially in girdles and limbs. Incipient stage of milking habit. Lower jaw with new or mammalian type of joint with skull (*i.e.*, between dentary and squamosal bones). Various aberrant specializations in modern representatives.

(14) *Pre-trituberculate mammal.* Jurassic. Lower jaw of primitive mammalian type, crowns of lower cheek teeth with elevated, three-cusped "trigonid" and low, small "talonid" or heel.

(15) *Pre-opossum,* conservative Metatherian. Cretaceous. Not near direct line to placentals but retaining many primitive skeletal features, especially in skull and dentition. Young probably born in very incomplete condition. Brain with only beginning of "neopallium"; corpus callosum not developed.

(16) *Cretaceous insectivorous placental.* Skull of small generalized insectivore type. Small brain with large olfactory lobes. Brain in modern descendants with corpus callosum. Upper cheek teeth with incipiently divided main cusp (paracone) and low inner spur (protocone). A placenta developed in modern relatives.

(17) *Primitive tree-shrew.* Basal Eocene. Incipient adaptations of hands and feet for tree-climbing. Skull essentially as in No. 18, that is, lemur-like but with unreduced olfactory chamber. Skeleton of generalized placental type. Modern tree-shrews retaining many primitive characters.

(18) *Stem Primate.* Lower and Middle Eocene. Adaptations for arboreal habits deeply stamped on hands and feet of grasping type. Dental formula $I^2_2C^1_1P^4_4M^3_3$. Eyes large, orbits with postorbital rim.

(19) *Eocene Pre-tarsioid.* Known forms aberrantly specialized; but more generalized stage should be near to main line. Eyes large, protruding forward, interorbital space reduced. Brain very wide, jaw short, wide posteriorly, pointed in front. Extremities grasping (grasping-hopping in known forms). Premolars typically $\frac{3}{3}$. *Parapithecus* possibly belongs here.

(20) *Stem Old World monkey.* Pronograde or essentially quadrupedal, with grasping hands and feet. Dentition $I^2_2C^1_1P^2_2M^3_3$. Cheek teeth in recent forms aberrantly specialized; *i.e.*, with well developed cross-crests. Nose catarrhine (V-shaped nostrils). Orbits separated from temporal fossae by bony partition.

(21) *Pre-anthropoid* (*Propliopithecus*). Lower Oligocene. Ancestral gibbons with short, deep lower jaw, more primitive lower canines and premolars. Dentition: $I^2_2C^1_1P^2_2M^3_3$. Molars with five cusps. Frugivorous. Recent gibbons overspecialized for upright progression by brachiation, with excessively long arms and legs; nevertheless retain certain monkey characters (*e.g.*, traces of ischial callosities). Brain less advanced than those of the chimpanzee and gorilla.

(22) *Mid-Tertiary anthropoid group.* Ranging from Spain, through France, Germany, Austria, Egypt, East Africa to India and (later) to South Africa. Lower molars with five cusps and "*Dryopithecus* pattern." Limb bones of anthropoid type. Brain capacity of recent great apes ranging from 290 to 610 cc. (Keith).

(23) *Southern Ape* (*Australopithecus*). Pliocene or Pleistocene of South Africa. This "ape-child" skull probably belonged to a race of adults with muzzles more ape-like than its own. Nevertheless, its deciduous teeth and first true molars, while primarily of the "*Dryopithecus*" type, are not very far below the earlier human levels.

(24) *Early Human Stage.* Lower Pleistocene or earlier. Represented at least by *Pithecanthropus* of Java and *Sinanthropus* of China. Vertically low skulls with strongly projecting brow-ridges. Brain of relatively low type; endocranial capacity 900 ± cc. (Dubois). Clear traces of "*Dryopithecus* pattern" in lower molars of Ehringsdorf young.

(25) *Homo sapiens.* Pleistocene and Recent. Braincase typically high, with little or no brow-ridges. Cranial capacity: racial means ranging between 1200 and 1500 cc. (Hooton). Skeleton adapted for upright bipedal posture, but hands and feet retaining many clear traces of generalized ape ancestry. Lower molars often four-cusped, with traces of "*Dryopithecus* pattern" usually on m_1. Brain retaining many unmistakable marks of derivation from an anthropoid stage, but with progressive development of centers and areas associated with speech and verbalized thinking.

As to the possible future of mankind, it is pointed out that, to judge from the history of many other new groups (not species), and in consideration of his cosmopolitan distribution, mankind should be a "good risk" for survival for an indefinite period.

OBITUARY

JOHN JOSEPH CARTY—AN APPRECIATION

WHEN in the early morning hours of Tuesday, December 27, General John J. Carty died in the Johns Hopkins Hospital, after a valiant but unsuccessful fight to overcome the shock of a major operation, the field of science, the profession of engineering and the community of intellectual life in the United States suffered a great loss. Nor was this loss confined to the nation of which he was a citizen, which he loved with that intellectual fervor which only the great possess, and which throughout his life he had served with such steadfast devotion. In many countries, from those of Europe to far-off Japan, Carty, his works and achievements and his philosophy of life were known and admired.

From every country which has felt during the past half century the stirring of that new force which science and its application has brought into human living, men have at one time or another made the pilgrimage to New York to sit at Carty's feet and to learn and profit from his wisdom. It mattered not what language the pilgrims spoke, all profited from the contact and all returned whence they came not only with a realization of this profit, but also with the realization that they had acquired the lasting friendship of a wise man.

Nor were these contacts one-sided affairs. General Carty had an insatiable desire to enlarge his own fund of information and understanding. All who came in contact with him, from the most wise to the most frivolous and shallow, were subjects for his inquiry. He gave much and willingly of his store of knowledge and wisdom but in return, and frequently in ways unknown to his vis-à-vis, he exacted payment in full measure. At times this payment was in kind; more frequently than not it was in values quite foreign to the main subject-matter of the conversation. At the termination of the contact General Carty had invariably something new added to his already great store of knowledge—a bit of social history or custom, a hitherto unknown item of science, a peculiar slant of political thinking, or any other of the thousand and one things which involve the working of human emotions or the human mind.

His relentless search into the way human beings react and into the motives which guide their thought and action, and whose results he continually marshaled and remarshaled under the guidance of his incisively analytical mind, became a main source of his extraordinary capacity for being always at home in any company. Few men possess the capacity which General Carty had for meeting on a plane of complete understanding men and women of every social and intellectual gradation. It was a capacity which enabled him in every situation to give and receive knowledge and to influence the outcome of events in ways and in a manner which were frequently uncanny.

More than most men, General Carty had at one time or another actually put himself in the position of the other man in the wide variety of situations in which men exercise their powers, their frailties, their hopes and aspirations and their emotions.

For one who attained to such eminence, whose counsel and advice were so sought after in so many fields, and whose opinion always carried such weight, even with those who dissented from his conclusions, the record of General Carty's own writings, even in the field of his profession or that part of it which was his specialized interest—electrical communication—is surprisingly meager. Of course during his long active and creative career he produced a vast volume of letters, memoranda and reports, each bearing the imprint of a master mind but each concerned primarily with some specific question of the moment. At the same time lectures, addresses and articles of the kind which go commonly to build up a reputation for wisdom and which produce a far-reaching and lasting influence were remarkably few in number. Such as do exist are almost without exception just what one would expect from their author.

Why was it that a man who possessed and deserved the reputation which General Carty acquired made so little use of the tool which most men of ability esteem their most powerful weapon? The answer is clear to those in position to know him best. In part it was because he was always too busy seeking to solve the vast array of problems crying for solution, even though he always promised himself and others that he would some time write out something of what he had learned. In part also it was because the act of authorship was for him an incredibly laborious task. Only those of us who have been witness to this labor have any real appreciation of just how difficult and time-consuming it was for him to prepare an important document which would be a permanent record of his thoughts and conclusions and to which he would be willing to sign his name. This labor was not because he in any way failed to have a perfectly definite and clear picture of just what he wished to say, nor because he lacked the full vocabulary in which to express his thoughts. Rather it was because he did have complete clarity of mind and a full vocabulary. To him words and their arrangement were powerful tools which should not be lightly nor thoughtlessly employed. Every word and every sentence in any document of importance must, when finally chosen and ar-

ranged, convey to the reader the exact shade of meaning—no more, no less—that he had in mind. This habit and insistence made serious writing far too time-consuming an operation to be indulged in frequently.

Absence of a voluminous printed record does not mean, however, that General Carty left no substantial material evidence of his great creative ability. Modern telephony, whose development owes so much to him, has in the last analysis a very limited number of elements which are prime to its existence. Some, like the telephone itself, or the loading coil or the vacuum tube amplifier, are spectacular and well known. Others of equal or greater importance have become so much the commonplace of telephone engineering that few realize their fundamental character or that their creation was ever looked upon as an outstanding achievement.

The three most important of these foundation stones which are in use wherever telephony is employed are creations of General Carty. His invention of the "common battery" for supplying operating current from a single central office battery to any number of interconnected telephones made practical the commercial development of telephony in metropolitan areas.

His development of the high resistance bridging signal bell for subscribers substations to replace the theretofore universally employed low resistance series bell, tore the hampering shackles from a wide-spread extension in the use of the telephone. Every telephone set now in use employs such a signal.

Equally revolutionary and of a more distinctly scientific character was his discovery that the principal cause of cross interference between telephone circuits was electrostatic and not electromagnetic unbalance. This discovery and the rules which General Carty worked out for the proper construction of adjacent telephone circuits are now universally employed.

A characteristic of each of these achievements is that each came as the direct and logical result of what was one of General Carty's most powerful intellectual weapons—his ability to brush aside non-essentials and grasp the kernel of the problem. Many men had worked on each of the three things just mentioned. They were obvious obstacles to progress. They yielded readily to solution once General Carty had formulated simply and accurately the essentials of the problem and the nature of the answer required.

These things and a host of others similar but less important were personal creations. They belong to his earlier years. The great achievements of his later life and for which he is best known in the field of electrical communication are the achievements of a generalissimo. Long distance telephony over land, transoceanic radio telephony, the coordination of factors which render present-day telephony so marvelously easy bear scarcely a trace of General Carty as a creator of any essential new element. They are, however, almost as surely his creations as any of his earlier work.

He analyzed the problems, picked out the essential elements to be attacked, mobilized just the right forces, provided the supplies by selling confidence in ultimate success to those who must provide the supplies and inspired a sort of fanatic determination in those who looked on him as captain.

Although primarily concerned with scientific, engineering and organization matters in the field of electrical communication and most of all in the well-being and reputation of the Bell System, General Carty looked upon the whole field of science as his hunting ground. Many of his closest friends were men of distinction in fields of science far removed from those of electrical engineering or physics. Denied the privilege of any formal training in science he nevertheless acquired such an understanding in many fields of knowledge and research that masters there sought discussion with him.

Consideration of everything General Carty did shows always the same technique. Painstaking analysis of the problem; exact formulation of the questions to be solved; full consideration of every ascertainable obstacle, human or material, likely to be encountered; assembly of just the right forces and then when all was ready a feverish onslaught quite in contrast with the slow and methodical preparations. But no matter how feverish the attack once all was ready, there was never any lessening of meticulous attention to detail where he thought that detail important. This technique he applied with infinite variations and shades to the material problems of electrical communication; to the delicate political problems involved in the daring attempt to demonstrate transatlantic telephony in the midst of the World War; to the essentially human problems of organization which created the perfect battalions which made the Signal Corps Reserve preeminent; to his part in creating the National Research Council, or to making certain that the solemn ceremonies of the burial of the Unknown Soldier should be broadcast to expectant thousands across the continent unmarred by accident.

Who but General Carty would have realized that the most probable cause of disaster in these august ceremonies would lie in forgetfulness on the part of the great participating personages under the emotional stress of the occasion? Or who but he would have known that insurance of success lay in the little piece of carpet which he himself tacked in exactly the right place where each speaker was to stand?

The lasting record of General Carty's character and

achievements is in the art of communication, of which for nearly fifty years he was an outstanding leader; in the citations by which a large number of great institutions justified their grants to him of honorary degrees or medals of distinction and in the archives of the Departments of State of his own and other nations which conferred upon him high orders in recognition of services rendered in the cause of making this world a better place in which to live.

To General Carty, science and the methods of scientific thought were never narrow things or things apart from the great problems of a fuller life. Nor were the great institutions and academies of science mere machinery for putting the capstones of acknowledged success on recognized achievement. To him their raison d'être was their unique opportunity for service.

It was in this light that he looked upon the National Academy of Sciences, an essentially undemocratic institution in a democratic country. It was knowledge of this feeling which caused his associates to create there the medal which bears his name and of which the academy later made to him its first award. It was for him the most pleasurable and satisfying token of love and esteem which those associates could render since it gave assurance of enhanced opportunity to the academy for lasting service. That he did not live to receive the medal is a source of regret to his friends. To him it mattered little.

F. B. JEWETT

SCIENTIFIC EVENTS

THE NATURAL HISTORY OF MOUNT EVEREST

IN view of the forthcoming Everest Expedition, a small selection of the specimens brought back by the expeditions of 1921, 1922 and 1924 has been arranged at the British Museum (Natural History), South Kensington, to illustrate conditions upon the mountain. According to the London *Times*, the general appearance of the upper ranges of Everest is excellently illustrated in a number of enlarged photographs. One of these shows how the high winds, even outside the seasons of the monsoon, give rise to whirling clouds of dry snow. The article in the *Times* continues:

A sectional elevation shows the altitudes up to which various forms of life were found, and objects from every department indicate the peculiarities of the natural history of the mountain. Beetles were found at a height of 16,500 feet, butterflies up to 17,000 feet, moths as far up as 18,000 feet. Each of these specimens had its idiosyncrasies; the butterflies and moths clung with their wings to the mountain side against the high wind; the beetles stiffened out and rolled; and even the ants were remarkably torpid.

The grasshoppers shown from the higher altitudes are all wingless, but are related, save for one endemic group, to winged varieties elsewhere. It is curious to note how much smaller were two specimens, within the same species, which were found at 10,000 feet, than two similar examples from the 7,000-foot level. Spiders were found above the snowline and up to 22,000 feet; they live, apparently, upon diminutive insects which themselves must exist on inconspicuous vegetable life.

Sheep were found up to 20,000 feet on the borders of the lichen-zone, but the highest recorded altitude to be reached by a mammal (20,100 feet) was attained by the Royle's pika or Wollaston's pika (mouse-hare), of which a number are on view.

In general, the fauna below 16,000 feet is of essentially the same type as that of the adjacent areas of Central and Southern Asia, while above 16,000 feet its affinities are predominantly Palearctic. The animals are, however, frequently of smaller size than their lowland relatives. The highest nesting birds were found at 17,000 feet; finches were seen migrating at 21,000 feet, and choughs followed the climbers as high as they went.

The plants found on Everest include willows, primulas, gentians, blue poppies and others known to Western gardeners. The short duration of the growing season (three to four months), the exposure to wind and cold, the brightness of the light, the pressure of snow, the distance of water from surface, the scarcity of insects and the poorness of soil, however, all help to make plant life difficult. The plants on screes and cliffs have a very long, spongy taproot, enabling them to reach down to the moisture and to resist the movement of the loose stony material.

The Himalayan range is comparatively Recent, and reached its present form only in Pliocene times. Fossil ammonites from the 14,000-foot level of the Tibetan plateau show the creatures which formerly lived in the sea, which covered the site of the great range. Examples of Recent rocks were collected up to 27,000 feet.

The exhibition, which has been arranged in the Insect Gallery by Dr. Anna B. Hastings and M. M. Burton, will remain open between six months and a year.

FORESTRY PROGRAM FOR THE SOUTH-EASTERN STATES

A FORESTRY program designed to meet the needs of the eight southeastern states has been adopted by the Southeastern Council according to an announcement made by Colonel J. W. Harrelson, director of the North Carolina State Department of Conservation and Development. This program is given below.

1. Encouragement of teaching forestry in public schools and colleges and the development of an appreciation on the part of the general public of the benefits of forest conservation.

2. Speedy extension of each state's forest fire prevention and control system to include all forest lands needing systematic protection.

3. Promotion of comprehensive economic surveys to provide for land-use zoning to designate areas best suited to agricultural development, private forestry and public forests.

4. Development of a coordinated system of publicly owned forests, national, state and local, to be used for timber production, demonstration of improved timber growing and fire control methods, wild life conservation, public hunting grounds and recreation.

5. Equalization of taxes so that forest property will not carry a greater burden, in proportion to its value, than do other classes of property.

6. State-wide assistance to landowners in the handling of their forestry problems.

7. Encouragement of reforestation of idle and eroding lands by maintaining state forest tree nurseries to provide suitable planting stock.

8. Extension of investigations by federal forest experiment stations and suitable state research agencies upon the various subjects fundamental to economic handling of forest lands.

9. Speedy extension to the entire southeast of a survey inaugurated under the McNary-McSweeney Act to supply information now woefully lacking as to the present quantity and condition of standing timber, its rate of growth and rate of depletion and market demands for the several types of timber.

10. Recognition by the Federal Government of landowners engaged in the practice of forestry as eligible for the same loans, assistance, grants and privileges as are accorded to the producers of other crops that spring from the soil.

THE WISCONSIN ALUMNI RESEARCH FOUNDATION

A PATENT on another important scientific discovery which will aid in the restoration and protection of health has been assigned to the Wisconsin Alumni Research foundation at the University of Wisconsin, according to an announcement made by Dr. Harry L. Russell, director of the foundation.

A broad basic patent on inorganic compounds of iron and copper for the prevention and treatment of anemia has been granted to Professor Edwin Bret Hart, of the department of agricultural chemistry, University of Wisconsin, and has been assigned to the foundation, becoming one of a number of health-giving discoveries controlled by the foundation in the interests of public welfare. Among the most important of these discoveries is Professor Harry D. Steenbock's process for imparting the health-giving vitamin D properties to food.

The latest patent assigned to the foundation covers various aspects of Professor Hart's discovery of the effect which copper has on unlocking the therapeutic powers of iron in restoring proper hemoglobin content to the blood of anemia patients. Professor Hart made his discovery in 1928 after three years of research and the patent application has been pending since that time.

The foundation has obtained patent control of the discovery, Dr. Russell explained, in order to insure the therapeutic presentation of the compounds in accord with the proper formula. This control is gained through a system of granting licenses for the use of the discovery and other patented articles, and thus the foundation is able to make available these discoveries to the public, while at the same time protecting the public from fraudulent and unchecked exploitation of uncontrolled commercial use.

Professor Hart's experiments showed that iron, long accepted as beneficial in some cases of anemia, required the addition of copper as a catalytic agent, and that "iron" which proved actively useful in treatment of anemias contained traces of copper as a contaminant. The research was narrowed to a study of inorganic materials when vegetable and animal tissues were burned to an ash before being fed and the catalytic properties were found to persist. The blue appearance of such ash led to successful experiments with copper.

Rabbits, chicks and rats developed severe anemia when placed on an exclusive diet of milk, a food naturally deficient in copper, but they evidenced rapid hemoblogin improvement to normal when minute quantities of copper were introduced in their foods.

In application to a hundred cases of secondary anemia in children, it was found in a New York hospital that the administration of copper and iron together increased the hemoglobin content from 64 per cent. to 84 per cent. in four weeks. The red blood cells gained in numbers accordingly. The appetite of the children treated improved materially, and they gained in alertness, weight and color. The copper-iron preparation was mixed with their milk or other foods which it was found neither to discolor nor to alter in taste.

THE PACIFIC DIVISION OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

BY invitation of the University of Utah, the seventeenth annual meeting of the Pacific Division of the American Association for the Advancement of Science and associated societies will be held in Salt Lake City. The period June 12 to 15, 1933, has been approved for the meeting. Up to the present time the following societies have announced their intention to participate:

American Association of Economic Entomologists, Pacific Slope Branch. *Chairman,* Program Committee: G. I. Reeves, University of Utah, Salt Lake City.

American Chemical Society, Pacific Intersectional Division. *Chairman,* Program Committee: C. R. Kinney, University of Utah, Salt Lake City.

American Physical Society. Local Secretary for the Pacific Coast: Leonard B. Loeb, University of California, Berkeley.

American Phytopathological Society, Pacific Division. *Secretary:* B. A. Rudolph, Route 1, Box 232, San Jose.

American Society of Ichthyologists and Herpetologists, Western Division. *Secretary:* L. E. Griffin, Reed College, Portland, Oregon.

Astronomical Society of the Pacific. *Secretary:* C. H. Adams, 506 Merchants Exchange Building, San Francisco.

Botanical Society of the Pacific, Pacific Section. *Secretary:* George R. Hill, American Smelting and Refining Company, Salt Lake City.

California Academy of Sciences. *Secretary:* Susie M. Peers, Golden Gate Park, San Francisco.

San Francisco Aquarium Society. *Secretary:* Mrs. Ethel Seale, Steinhart Aquarium, Golden Gate Park, San Francisco.

Society of American Foresters, California and North Pacific Sections. *Secretary:* H. L. Person, University of California, Berkeley.

Society for Experimental Biology and Medicine. *Secretary:* M. L. Tainter, Stanford Medical School, San Francisco.

Utah Academy of Sciences. *Secretary:* Vasco M. Tanner, Brigham Young University, Provo.

Western Society of Naturalists. *Secretary:* E. G. Moberg, The Scripps Institution, La Jolla, California.

Western Society of Soil Science. *Secretary:* E. E. Thomas, Citrus Experiment Station, Riverside, California.

Members wishing to present papers before any of the scientific sessions are asked to submit the titles of their communications to the secretary or program chairman of the appropriate society. Alternatively, titles may be sent to the office of the Pacific Division. Members of non-participating societies desiring to present papers are cordially invited to do so. A title submitted to any of the above will be placed upon the program of the society most suitable to receive it.

A preliminary announcement containing general information about the meeting will be distributed late in March. The program containing titles of all communications will be mailed about June 1.

SCIENTIFIC NOTES AND NEWS

DR. H. SPENCER JONES, astronomer at the Cape of Good Hope Observatory, has been appointed astronomer royal at the Royal Observatory, Greenwich, in succession to Sir Frank Dyson, who on reaching the age of sixty-five years will retire from the public service on February 28. Dr. Jones was chief assistant at the Greenwich Observatory from 1913 to 1923.

DR. PAUL D. FOOTE, director of research of the Gulf Oil Companies and lecturer at the University of Pittsburgh, was elected president of the American Physical Society at the recent Atlantic City meeting. He succeeds Dr. W. F. G. Swann, director of the Bartol Research Foundation of the Franklin Institute.

A SOUND film presenting Dr. William H. Welch speaking on "Reminiscences of the Early Days of the Medical School" will be shown at the Rockefeller Institute for Medical Research, New York, at four o'clock on January 18. Admission is by invitation.

DR. EMIL ARTIN, professor at Hamburg, and Dr. Emmy Noether, professor at Göttingen, have been awarded the Ackerman-Teubner Memorial Prize, Leipzig, for research in mathematics.

DR. R. S. BASSLER, head curator of the department of geology of the U. S. National Museum, has been elected an honorary member of the Society of Natural History of Tartu, Esthonia, in recognition of his work on the geology and paleontology of that country published as a museum bulletin some years ago.

The British Medical Journal reports that the Dr. Sophie A. Nordhoff-Jung Cancer Prize for the best work in the field of cancer research in recent years has been awarded to Professor Max Askanazy, of the University of Geneva, in recognition of his experimental research work and his critical presentation of larger and general problems in the same field. The commission of award was composed of Professors Borst, Doederlein, von Romberg and Sauerbruch.

WE learn from *Nature* that the Hopkins prize for the period 1924–27 has been awarded by the Cambridge Philosophical Society to Professor G. I. Taylor, Yarrow research professor of the Royal Society, for his researches on hydrodynamics and on the deformation of crystals; and the prize for the period 1927–30 to Professor P. A. M. Dirac, who was recently elected Lucasian professor of mathematics in the University of Cambridge, for his researches on the theory of quantum mechanics.

AT their meeting at Atlantic City on December 27, the trustees of the Mathematical Association of America awarded the Chauvenet Prize of $100 to Professor G. H. Hardy, of the University of Cambridge, England, for his paper entitled "An Introduction to the

Theory of Numbers," which appeared in the *Bulletin* of the American Mathematical Society, Vol. 35 (1929), pages 778–818. This prize is awarded every three years for the best expository paper on a mathematical subject published in English by a member of the Mathematical Association. The award covered the triennium 1929–31.

ON the occasion of the seventieth birthday of Emmanuel de Margerie, the French geologist, thirty-seven American geologists united in sending him a message which included the following: "A few of your American friends and colleagues take this occasion to send you greetings from across the sea. We are mindful of your scholarly acquaintance with the literature of American geology; we appreciate your generous interest in the scientific studies of your American colleagues; and we recall with peculiar pleasure the days when you brought to this country the rich fruits of your ripe experience. And so we gladly join in sending you affectionate greetings, and our cordial wishes for many more years of health in which to enjoy both your own scholarly pursuits and the high honor and esteem in which you are held throughout the world."

DR. CHARLES SINGER, of the University of London, who went to California as Herzstein Lecturer in Medicine in 1930, and who has been professor of the history of science for the past year, has left San Francisco for a trip around the world on his way to England. A farewell luncheon was given to Dr. Singer and Mrs. Singer at the Bohemian Club by the California Medical History Seminar, with Dr. Chauncey D. Leake, professor of pharmacology at the University of California Medical School, presiding.

IN recognition of the work of Dr. Louis E. Wise in the department of forest chemistry at the New York State College of Forestry, Syracuse University, a hand-illumined copy of a resolution by the faculty of the college has been signed by each member and forwarded to him. Dr. Wise, who had been professor of forest chemistry at the college since 1919, resigned on July 1 owing to illness. Through the action of the Board of Trustees, he retains his connection with the college as professor emeritus. His present address is Winter Park, Florida.

DR. COLLIER COBB, since 1893 professor of geology at the University of North Carolina, has retired from active service.

DR. JAMES A. KENNEDY has been appointed director of the division of diagnostic laboratories at the University of Rochester School of Medicine and Dentistry.

DR. EDWARD DELEHANTY has been promoted to the professorship of neurology in the University of Colorado School of Medicine, Denver, succeeding the late Dr. George A. Moleen.

DR. HENRY S. HOUGHTON, dean of the Medical College at the University of Iowa, has been appointed professor and associate dean of the division of the biological sciences at the University of Chicago and director of the south side clinics. Dr. Houghton assumed his post on January 1. As director of the clinics he will succeed Dr. Franklin C. McLean, who has become professor of physiology. Dr. Houghton will be associated with Dr. Frank R. Lillie, dean of the biological sciences, and will supervise the medical work of the various university hospitals and clinics.

DR. REGINALD FITZ, associate professor of medicine at the Harvard Medical School, has been elected a member of the National Board of Medical Examiners.

WE learn from *Museum News* that Arthur C. Parker has resigned as director of the Rochester Museum of Arts and Sciences, effective December 31. The budget cut of the City Council reduced the museum appropriation to about $6,000, making impossible a continuation of the institution as an effective organization. Mr. Parker was recently commissioned by *New York History,* the official organ of the New York State Historical Association, to write "A Manual of Museology for History Museums." A consulting board has also been appointed to participate in the project. Its members include Clark Wissler, Hardinge Scholle, Robert W. Bingham, Alexander J. Wall, Julian P. Boyd and Stephen H. P. Pell.

GOVERNOR A. HARRY MOORE, of the State of New Jersey, has appointed Dr. Robert P. Fischelis, secretary and chief chemist of the Board of Pharmacy of the State of New Jersey, a member of the State Educational Survey Commission. The duties of the commission are to survey the educational system of the state and to propose recommendations for an essential program of modern education and methods of financing it. The commission includes the State Commissioner of Education, a number of school superintendents and principals and a number of prominent laymen, all of whom serve without pay.

AT the annual meeting of the Board of Directors, which followed the annual meeting of the National Committee for Mental Hygiene, the following officers were reelected: *Honorary president,* Dr. William H. Welch, of Baltimore; *President,* Dr. Charles P. Emerson, of Indianapolis; *Vice-Presidents,* President James R. Angell, of Yale University; Dr. William L. Russell, professor of psychiatry at the Cornell University Medical College; Dr. Bernard Sachs, of New York; *General Director,* Dr. C. M. Hincks; *Treasurer,* Frederic W. Allen, and *Secretary,* Clifford W. Beers. Dr.

Arthur H. Ruggles, of Providence, was reelected chairman of the Scientific Administration Committee; Dr. Augustus Knight, of New York, chairman of the Executive Committee, and Mortimer N. Buckner, of New York, chairman of the Finance Committee.

DR. EUGENE LINDSAY OPIE, professor of pathology at Cornell Medical College, and Dr. Louis Israel Dublin, vice-president of the Metropolitan Life Insurance Company, have been appointed Cutter Lecturers on Preventive Medicine at Harvard University for the academic year 1932–33.

DR. FRANCIS R. FRASER, professor of medicine at the University of London, will give the third series of Abraham Flexner Lectures at Vanderbilt University School of Medicine, Nashville, during February and March. Dr. Fraser will lecture on "The Principles of Therapeutics" and will hold clinics under the auspices of the department of medicine. The Abraham Flexner Lectureship, founded at Vanderbilt in 1927 by Mr. Bernard Flexner, New York, is awarded every two years. Previous lecturers have been Dr. Heinrich Poll, director of the Institute of Anatomy, University of Hamburg, Germany, and Sir William Hardy, director of the Low Temperature Research Station, Cambridge, England.

THE REV. JAMES B. MACELWANE, S.J., Dean of the Graduate School and professor of geophysics in St. Louis University, addressed the St. Louis University Sigma Xi Club on December 12 on "Some Results of Recent Studies at the St. Louis University Seismographic Stations."

DR. FREDERIC H. LAHEE recently completed an extensive trip made for the purpose of addressing various groups of members of the American Association of Petroleum Geologists, of which he is president. His itinerary included San Antonio, Los Angeles, San Francisco, Seattle, Calgary, Denver, Wichita, Oklahoma City and Tulsa.

ON the night of December 12, the geologists of Greater Chicago met to dine together and to form the Geological Society of Chicago. After brief organization proceedings an executive committee was elected to direct later meetings. Professors Edson S. Bastin and John R. Ball spoke in honor of the late Professor U. S. Grant, after which a resolution in memory of Dr. Grant was drafted and unanimously approved. The meeting was then addressed by Professor Warren J. Mead, of the University of Wisconsin, on "The Hoover Dam." Some seventy men and women, representing industrial companies, museums and universities of Greater Chicago, attended.

THE American Physical Society and the American Optical Society will meet at Columbia University, New York City, on Friday and Saturday, February 24 and 25.

THE annual general meeting of the American Philosophical Society will be held at Philadelphia on April 20, 21 and 22, beginning at 2 P. M. on Thursday, April 20.

THE new research laboratory of Merck & Company, Rahway, New Jersey, will be dedicated on March 1. The structure, started in 1932, will house in the south wing laboratories for pure research in biochemistry and pharmacology while the north wing will be used for applied research. The central section will be used for offices of the directors of research, Dr. R. T. Major, director of pure research, and Dr. W. H. Engels, director of applied research. Dr. Joseph Rosin, technical director of the company, and his staff will work on the second floor, which will also house a library.

DR. WALTER M. SEWARD, of Brunswick County, Virginia, has left his entire estate, valued at approximately $250,000, to the University of Virginia. Under the terms of his will, the lands and personal property bequeathed to the university will be used for "practical demonstrations in the art of forestry," and "toward the maintenance and upbuilding of the school of forestry at the university."

BY the will of the late William Boyce Thompson the American Museum of Natural History receives Colonel Thompson's jades and crystals, valued at $107,000, and in addition $20,000 to prepare quarters for the collection and $50,000 to maintain it and make additions.

IT is reported from Mexico City that the State of Oaxaca, with the aid of funds from the federal government, will build a museum to house the relics unearthed during the past two years by the Mexican archeological expedition directed by Professor Alfonso Caso.

Nature reports that an addition of value has been made to the possessions of the Royal Society for the Protection of Birds in the Eastwood Nature Reserve, Stalybridge. The reserve, originally extending to about eight acres, was bequeathed by the Right Honorable John F. Cheetham, together with £5,000 for its upkeep. To this has been added an adjacent four acres, with £500, by a niece of the donor, Mrs. Wimbush, of Taunton. The reserve is a beautiful ravine within the public park given by Mr. Cheetham to Stalybridge, and his wish that it should be kept in a natural state as regards fauna and flora will insure the continuance of a sample of wild nature in the heart of an industrial area. Already there is abundance of wild plants and unexpected variety of birds.

THE eighth cumulative volume of the Readers' Guide to Periodical Literature, covering the period from

January, 1929, to June, 1932, has been published by the H. W. Wilson Company of New York City. The index is issued monthly, the numbers are cumulated throughout the year and bound volumes are issued annually. These are then superseded by the permanent volumes. The Guide covers the complete contents of the periodicals that it indexes by subjects and authors. 1,047 periodicals are indexed, including SCIENCE, *School and Society* and *The Scientific Monthly*. The first two of these are among nine weekly journals whose contents are selected as most worthy of permanent record and reference.

THE next award of the Alvarenga Prize, amounting to about $300, will be made on July 14, 1933. Essays may be on any subject in medicine and should represent an addition to the knowledge and understanding of the subject based on either original or literary research. The prize was not awarded in 1932. Communications should be addressed to Dr. John H. Girvin, secretary, 19 South Twenty-second Street, Philadelphia.

ACCORDING to the *Journal* of the American Medical Association, the Rumanian Academy of Sciences controls a fund, collected mainly from bequests, the interest of which, according to the wish of the testator, is awarded to the best literary works that have appeared during the year. The committee on awards has just finished reading the contributions for 1931, and out of the many awards the following were given for medical treatises: The Oroveanu prize of 70,000 lei has been awarded to Dr. Mina Minovici, professor of forensic medicine at the University of Budapest, for the second volume of his "Manual of Forensic Medicine." The Riegler 6,000 lei prize was awarded to Professor Peter Tomescu for his "Clinical Experimental Studies," which will be shortly translated into German. The Adamachi prize was given to Dr. Valeriu Bologa for his work "The History of Scientific Medical Work in Rumania," read in part at the recent International Congress on Medical History. The Constantinide prize was divided between Aurel Voina, lecturer at the University of Bucharest, for his treatise "Prostitution and Venereal Disease in Rumania," and Drs. Staicovici and Westfried for their monograph dealing with public health affairs of the city of Bucharest in the post-war years.

A CORRESPONDENT writes: "Cottonwood Cave on the Lincoln National Forest in New Mexico has been used for a goat shed for a great many years, also as a bat loft perhaps for thousands of years; consequently there are great deposits of guano in the bottom of the cave. As it is very rare that any water runs into the upper part of this cave, the deposit has become very dry. Presumably some visitor started a fire in the litter, not knowing that it would continue to burn. Judging from the distance it traveled, the fire had been burning for about three weeks when it was first discovered. At that time, the gas formed by the burning nitrates was so strong that the party could not go down to the fire. However, when it was visited by Supervisor O. Fred Arthur and Mr. Musgrave on September 24, the fumes were not bad except at the entrance to the cave. Fire guards were sent into the cave and put out the fire by packing water from a supply further down in the cave. An interesting phase of the fire was that the gas, evidently nitric acid gas, was so strong that it killed the leaves on oaks and maples at the mouth of the cave and about 200 feet from the fire. At no time during the fire was there enough heat to kill these leaves."

DISCUSSION

A FORGOTTEN EVOLUTIONIST

ON looking through the volumes of the short-lived *Archiv für Zoologie und Zootomie* my attention was attracted to an article (Bd. III, p. 167, 1802) entitled "Ueber den ursprünglichen Stamm des Menschengeschlechts," by D. Schelver. Being curious to see what the writer would say upon this topic in the year 1802, I discovered that the article contained a most interesting speculation on the probable original home of the human species and the source from which man was derived. Schelver takes issue with the then prevailing doctrine that man originated somewhere in southwestern Asia, urging that we can not legitimately argue from the origin of culture to the origin of the human race. The natural place in which to seek for the origin of man, he argues, is the region in which the most primitive men are living at the present time. Basing his conclusion on a number of anthropological characteristics, as well as cultural development, Schelver contends that the Negroes are the most primitive members of the human family, and that Africa must, therefore, have been the original cradle of the human race. But whence the Negroes? The Negroes, however, are far from representing the original ancestors of men. They have progressed far, both culturally and structurally, from the original human beings. It is no mere coincidence, according to Schelver, that Africa is the home of both the Negroes and the anthropoid apes. But man can not be derived from any existing species of anthropoids. "I shall

not assert," says Schelver, "that the original natural man (Naturmensch) came from any species of ape at present known, because I can not support this by positive proofs; and since we know quite as little of the original source of the apes, as of the human family, the apes may represent a degenerate branch of the original stem of the human species. I am acquainted with no distinguishing characteristic, however, which sharply separates the apes from human beings."

". . . The bodily nature of the human race must, in its origin, completely integrade with that of animals, and it is not improbable that, for example, we may discover hairy quadrupeds with the capacity for becoming human beings. . . . As to lowly origin, man is clearly worthy of all the more honor the lower the creatures from which he was descended."

Language, says Schelver, is a product of culture. "Der mensch hat sie erfunden, selbst geschaffen." The linguistic shortcomings of the apes, it is suggested, may be associated with the possession of vocal sacs which may, as was suggested by Sömmering, act as an impediment to the imitation of sound. These sacs are lacking in man, who, on the other hand, has another organ in a somewhat similar position, namely, the thyroid gland, which is stated to be absent in the apes. At any rate, the thyroid was not mentioned by Camper, and Schelver remarks that it could scarcely have escaped being noticed by so attentive and accurate an observer. Since the apes have vocal sacs, which man has not, and since man has the thyroid, which Schelver is persuaded is absent in the apes—"aber so viel mir bekannt ist," he cautiously adds—the hypothesis is advanced that the mysterious thyroid, whose function was so long sought for in vain, might represent the degenerate vocal sacs of the anthropoids. This conclusion is supported by certain statements concerning the outlet of the thyroid, which rest upon no better foundation than the alleged absence of this organ in the apes. That Schelver should have been led astray in his attempt at homologizing is quite natural when one considers the facts at his disposal. The point of chief interest is that the attempt was made at all.

What caused the human and anthropoid stems to diverge is a problem for which Schelver has no solution to offer. While his evolutionary concepts have much of the vagueness that characterizes the speculations of the earlier transformists, it is clear that he regards man as having a common origin with the higher apes, and that the higher types of animals are derived from lower ones, as is indicated by his reference to the genealogical table of organic life, "*der Stammtafel der ganzen lebenen Schöpfung, . . . die bis an das erste punctum saliens alles Lebens zurückführet.*"

S. J. HOLMES

UNIVERSITY OF CALIFORNIA

A VICIOUS CIRCLE IN CYTOLOGY

THE existence of rings and sometimes strings of chromosomes has been known for a number of years and apparently first attracted marked attention in the case of the genus Oenothera. This genus is particularly unfavorable for cytological investigation on account of the extremely small size of its nuclei. It has accordingly been unsuitable for working out the fundamental significance of ring formation. Much more suitable material for such investigations is supplied by the monocotyledonous family Tradescantiae, which have been investigated by various American and European cytologists. The conclusion has been reached that the rings of chromosomes, where they occur, are series of univalents which have more or less become confused with one another and pass over to opposite poles in approximate alternation at the metaphase of the reduction or meiotic division. Unfortunately, this statement is palpably incorrect. Apparently it is due to the study of the material by means of excessively thick sections or by the smear method. Both of these procedures have the fault of obscuring important details. The situation in the case of the Tradescantiae has been studied by means of thin sections appropriately developed by approved methods of staining. It has become clear in this connection that the so-called synaptic mates are actually present in Tradescantia as normally elsewhere and that they present clearly the phenomenon of chiasmotypy, a phenomenon to which, by the way, apparently an entirely disproportionate amount of attention has been given in recent years. The pairs of chromosomes become somewhat indistinct in the pachytene stage which follows the advent of pairs. This is a common phenomenon at pachytene and it is amazing that it has not been noticed in this instance. The whole situation, in fact, suggests a surprising superficiality on the part of certain observers which is in marked contrast to the large claims which they have made on the attention of cytologists in general. It is quite obvious that in *Tradescantia virginiana,* for example, the process of meiosis follows perfectly that which is not uncommon in hybrids. The apparent serially arranged, miscalled univalent chromosomes represent in reality a segmented pachytene in which the synaptic pairs are lined up, back to back. This view of the matter harmonizes further with the observations of Hakansson on hybrid Godetias. Here he noted, while the species showed little or no so-called ring formation, that in

contrast this condition was quite often characteristic of the hybrids between species. Muentzing (1932) has more recently called attention to the same tendency in hybrids. There seems to be little excuse for the errors of those who have worked on the cytology of ring formation in the case of Tradescantiae. In the species of Oenothera, however, and in the Onagraceae in general, the formation of pairs in connection with meiosis is very obscure and their separation can in general only be clearly made out at the actual metaphase. The rings and strings in species of Oenothera are also nothing more than persistent pachytenes which become distributed as such to the metaphase plate. It is obvious, if the statements made here are well founded, that the results obtained by Belling, Darlington and Sax in regard to ring formation are without sound foundation in fact.

E. C. JEFFREY

TWISTED TREES AND THE SPIRAL HABIT

THE behavior of organisms is determined by the physical and chemical nature of their protoplasm and by their environment. The relative importance of hereditary material and environment has long been, and probably ever will be, a controversial subject. This is true because both factors always play a part, sometimes one and sometimes the other having the predominant influence. There is also the very natural tendency of an investigator to attach more significance to the point of view represented by his field of work. A student of protoplasm or of genetics will see in heredity a greater influence, and the ecologist will lay emphasis on environment, though the former must be aware of the fact that protoplasm has come to be what it is primarily because of environmental influences working through the ages. The relationship between hereditary reactions and developmental expressions is presented fully and well by Stockard.[1]

It has occurred to me that a protoplasmic interpretation of the twisting of tree trunks might be a logical view of this interesting behavior concerning which there has been much discussion on the pages of SCIENCE.[2-6] Certain observers[2,4,5] see in the prevailing direction of the wind an explanation of the twisting of tree trunks. Persistent winds might well bring about a twisting of the trunk, in support of which is the fact that trees exposed to the wind often assume an oval shape. There is also the report that twisted trunks rarely occur in the heart of a forest.[4]

Several years ago this subject was again brought to my attention by my friend, Mr. Philip Sawyer, of New York, who told me of the twisted trunks of trees (conifers) along the trail up Mt. Audubon in Boulder County, Colorado. The degree of twist varied considerably, from a very gradual one to a complete twist within a distance equal to twice the diameter of the tree. The clockwise twist was the more usual. The reverse twist was infrequent and occurred among the others. This last remark of Mr. Sawyer's increased my belief that tree trunks twist because of an innate tendency to do so and not because of environmental factors. I was, therefore, very much interested in the recent report by Herrick[6] on twisted trees in the forests of Louisiana. He examined 1,527 trees, of which 364 (23 per cent.) were straight grained, 811 (53 per cent.) showed a right-hand twist, and 352 (24 per cent.) showed left-hand twisting. He observed further the condition of the roots of 57 trees that had been uprooted. Of these, 31 (5 per cent.) showed twisting to the right, 7 (12 per cent.) showed left-hand twisting and 19 (33 per cent.) were straight. He adds that if prevailing winds were the cause it would be expected that the limbs on the one side of a tree would twist in one direction and those on the opposite side would twist in the opposite direction. Actually, however, the limbs of any one tree always twist in the same direction. Herrick, therefore, concludes that as there is both right and left-hand twisting in tree trunks of the same locality, and as the twisting of limbs is in the same direction on all sides of the tree, and as roots also show twisting, winds can not be the cause. Mr. Laurence Moyer adds the old apple tree as another common example of tree trunk twisting.

It is the purpose of the present paper to suggest that the twisting of tree trunks is but one manifestation of a wide-spread tendency in organisms to grow and move spirally, a tendency due to a heritable protoplasmic quality and not to environmental factors.

The formation of spirals is not limited to living things. Crystals show both right-hand and left-hand growth. The precipitation of salts in gels, which goes by the name of the Liesegang phenomenon, is ordinarily rhythmic, resulting in the production of concentric rings, but occasionally a perfect spiral is produced, for which there is no adequate explanation. Organisms, from the lowest to the highest, give various indications of a spiral habit. Schaeffer[7] reports that Amoeba travels in a spiral when moving along a thin glass rod or within a fine capillary tube. The spiral may be to the right or to the left for varying lengths of time, and may alternate frequently, although a species is predominantly to the left or to the right. The shells of mollusks are striking examples of the spiral habit in organisms. Both Mr. Sawyer and my colleague Dr. Zirkle reminded me of this

1 "The Physical Basis of Personality," 1931.
2 SCIENCE, February 13, 1931.
3 *Ibid.*, March 27, 1931.
4 *Ibid.*, May 22, 1931.
5 *Ibid.*, January 29, 1932.
6 *Ibid.*, November 4, 1932.
7 SCIENCE, July 10, 1931.

fact. The shells of Nautilus and Triton are examples; especially fine are the long, cornucopia-like spiral shells of *Terebra oculata.* Further inquiry brought from Dr. H. E. Crampton the interesting observation that sea snails in the South Pacific show both right- and left-hand twists, the latter being infrequent.

Schaeffer[8] has carried his observations on spiral movement in organisms to man, whom he regards as a spirally twisted right organism. This is true not only of the movements of man but of body structure as well. The gall-duct is the most conspicuously spirally twisted unpaired organ in man, and it is a right spiral. There are numerous other examples of spirally-twisted organs in animals. As for movement, when man is blindfolded he walks in a right spiral. (In this connection there is the old saying that hunters when lost in the woods walk in circles to the right, the circle getting smaller and smaller, *i.e.,* man walks in a spiral. One wonders if the habit which dogs have of turning round and round before finally settling down for a nap, is another manifestation of the spiral tendency in organisms.) Spiral walking in man is also regarded as due simply to the fact that most people are right-legged, as they are right-handed, which results in walking in a curve. But the curve is most often to the right, while right-leggedness should, it would seem, produce a left spiral. However, right-leggedness is a possible cause of spiral walking in man, which, if true, eliminates but one of the many examples of the spiral habit in organisms.

The spiral structure of trees is duplicated in the most delicate of plant cellulose parts, namely, the cotton fiber. Titus and his coworkers[9] report such a structure for the cotton fiber. Denham[10] enumerates four distinct classes of spirals in cotton fibers. The structure does not always proceed in the same direction but suffers more or less regular reversals. Balls[11] has presented a number of papers dealing with the twisting of cotton fibers. He states that reversal from dexter (right) to sinister (left) spirals occur in the same fiber. Causation of the reversals is physiological (*i.e.,* protoplasmic). Ordinary environmental influences do not affect the statistical peculiarities of the reversals. The spiral habit in plants is further illustrated by the tight wrapping of tendrils and of vines. Two vines may twist around each other and give as perfect an example of spiral wrapping as exists in the artificial wound fibers of a rope. It appears, therefore, that the tendency toward spiral growth is as characteristic of the cellulose framework of plants as it is of the parts of animals. The spiral twisting of cotton fibers is convincing evidence that the twisting of tree trunks is an innate heritable property, and not an environmental effect.

The evidence presented here indicates that spiral development among organisms is the expression of a wide-spread tendency which is protoplasmic in origin.

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[8] *Jour. Morph. and Physiol.,* p. 294, 1928.
[9] *Jour. Chem.,* 9: 114, 1932.
[10] *Jour. Textile Inst.,* 14: 86T, 1923.
[11] *Proc. Roy. Soc.,* London, 99: 130, 1926.

THE EXTINCT LAKE SAN AUGUSTIN, NEW MEXICO

A SEMI-ARID basin in western New Mexico, known as the San Augustin Plains, has been described by Bryan as an old lake basin.[1] To this extinct body of water he has given the name Lake San Augustin. Field work by the writer during the summer of 1932 not only supports Bryan's view, but has yielded detailed information on the extent and characteristics of this ancient lake.

The San Augustin basin lies in western Socorro and eastern Catron Counties, and is bordered on the north by the Bear, Gallinas and Datil Mountains; on the west by the Tularosa Mountains; and the south by a mountainous belt, including the O Bar O, Pelona and Tuera Mountains; and on the east by the Magdalena Mountains The basin is 60 miles long from northeast to southwest, and has a maximum width of about 20 miles. During the rainy season (July and August) ephemeral streams make their way from the mountains across broad alluvial slopes to two playas, the larger and westernmost of which is called locally the San Augustin Plains, and contains the lake basin herein described.

Lake San Augustin at its highest stage was about 32 miles long by 11 miles wide, with a surface at about 6,940 feet A. T. The lowest point in the basin is 6,776 feet A. T., and thus the greatest depth of the lake was about 164 feet. The shore lines of this and all the lower stages are strikingly marked by shingle beaches, spits and bay head bars, and by cliffs developed both on rocky mountainsides and on alluvial fans. These shore features form a descending series that indicates many lake stages, the details of which are yet to be worked out from a study of the field notes. At its highest stage Lake San Augustin was connected by a small channel with a basin farther east, as yet unstudied, that probably drained into Lake San Augustin. At all the lower stages Lake San Augustin had no possible outlet, and its waters must have been depleted by evaporation and underground seepage.

The highest beach has a constant altitude on all sides of the playa, and thus gives positive evidence that no differential earth movements have occurred

[1] Kirk Bryan, "Ground Water Reconnaissance in Socorro County, New Mexico," Seventh Biennial Report of the State Engineer, pp. 82–83, 1925–26.

here since the formation of this beach. The beaches can be traced across all the larger alluvial fans surrounding the playa, and thus show that these fans were formed before the lake existed. Subsequent fan development has been feeble. The lake is believed to have existed in the last (Wisconsin) glacial stage.

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SCIENTIFIC BOOKS

Faraday's Diary. Vols. I and II. Edited by THOMAS MARTIN, M.Sc., and published by order of the Managers of the Royal Institution of Great Britain, with a Foreword by Sir William H. Bragg, O.M., K.B.E., F.R.S. G. Bell and Sons, Ltd., London.

AFTER Faraday's death the Royal Institution received as a bequest from him a manuscript record containing an account of the experimental work which had been done by him in the years from 1820 to 1862. This record the managers of the Royal Institution decided to publish as a fitting memorial of their most distinguished director. When the publication is complete there will be seven volumes, of which two are now at hand, and the others may be expected within two years. Only 750 copies of the work will be issued, and these will be sold in sets. The price of a set is twelve guineas.

The task of editing this work was undertaken by Thomas Martin, M.Sc., general secretary of the Royal Institution. It has been admirably performed. So far as one can judge without comparison with the original manuscript, the transcription of the text has been carried out with accuracy. The peculiarities of spelling and the abbreviations used by Faraday have been retained, and obvious errors have been noted, with proper reference to the editor. The diagrams and sketches with which the manuscript abounds have been with great judgment and good taste removed from the body of the text and inserted either on the wide exterior margins of the pages or at the bottom below the letterpress. In the latter case the paragraphs to which the diagrams pertain are indicated. The result is that, while the diagrams are immediately available, the text can be read with continuous comfort. An extensive table of contents is prefixed to each volume, and references are made in it to Faraday's published papers in which the matter of the text has been incorporated. An index or synopsis of the whole work is promised for the last volume of the set. The books are beautifully printed, in excellent legible type, on wide pages, with large margins, and are well bound. The publishers, Messrs. G. Bell and Sons, Ltd., should be congratulated on their contribution to the value of the work.

Faraday's first scientific paper was published in 1816, at a time when, as he says of himself, his fear was greater than his confidence, and both far greater than his knowledge; at a time also when he had no thought of ever writing an original paper on science. The favorable reception given to it emboldened him to undertake other researches in the time that was left him after the many duties of his position as assistant in the laboratory had been performed. After a few years he evidently felt that he would be able to carry on research in a sufficiently consecutive way to make regular entries of his experiments advisable, and in September, 1820, he began the notes of his work which ended only with the close of his scientific activity, forty-two years later. They present a complete record of the experiments which he carried out in the laboratory of the Royal Institution. The only important things which he did which do not appear there are his studies of alloys of other metals with iron and steel, carried out by him in collaboration with Mr. Stodart; his researches on the manufacture of glass for optical purposes; and the work which he did for nearly thirty years as scientific adviser of the Trinity House, for the improvement of the lighthouse service.

As was to be expected of an assistant of Sir Humphry Davy, Faraday was first interested in chemistry. With the exception of the invention in 1821 of apparatus to exhibit electromagnetic rotations, most of the entries for the first ten years are concerned with chemical matters. They record the experiments which led to the discovery of two compounds of chlorine with carbon (1820), they describe the liquefaction of chlorine and other gases (1822); and they present the long series of observations which led to the isolation of benzene from coal oil (1825). Many other observations are recorded which led to nothing or to results of minor importance. In 1831 appears the first study —with the exception noted above—of a purely physical subject, the vibrations of plates and the formation of Chladni's figures.

From time to time in these years Faraday had evidently had in mind the possibility of an inductive effect produced by an electric current in a neighboring conductor. On December 28, 1824, he tried the experiment of bringing up a strong magnet to a wire carrying a current, with the expectation that the current would be thereby modified; but no effect was shown on a magnetic needle placed under a distant part of the circuit. On November 28, 1825, he looked for a current in a wire set parallel to another wire carrying a current, but could perceive no action. Again on April 22, 1828, he endeavored to find an effect produced by a magnet pushed through a ring of copper wire, with no result. Why some of these

experiments failed it is not easy to determine, unless it was that Faraday was looking for a steady effect, produced so long as the arrangement was maintained, and so either did not look for or did not notice the momentary effects produced while the magnet was moving or when the primary current was closed or broken. That this explanation is the true one may be supported by an entry made on August 29, 1831, the day on which his first successful observations of electromagnetic induction were made: "Hence effect evident but transient; but its recurrence on breaking the connection shews an equilibrium somewhere that must be capable of being rendered more distinct."

The course of Faraday's progress in the discovery of the induced current was entirely different from that of his exposition of the discovery in his "First Series of Researches" read before the Royal Society on November 24, 1831. His first successful observation was made with an iron ring wound with two coils of wire, one of which was joined with a galvanometer, the other to a battery. When the battery circuit was made or broken, a temporary current appeared in the galvanometer. This experiment is the same as that reported by Joseph Henry as made by him before he had any knowledge of Faraday's method. On September 24 Faraday records his obtaining the induced current in a coil wound around an iron bar when the ends of the bar were in contact with the opposite poles of two bar magnets and the other ends of these magnets were brought together or separated. "Here distinct conversion of Magnetism into Electricity."

The first record of an induced current produced in a circuit by making or breaking a current in a neighboring circuit "without the presence of iron" was made on October 1. It was not until October 18 that this effect was confirmed not only with the galvanometer but by using the induced current in a helix to magnetize needles. This observation is the one with which Faraday begins his exposition.

The observation described by him in §18 of the production of the induced current in a circuit made in the shape of a large W, to which another similar circuit carrying a current was moved up or from which it was removed is not recorded in the diary until December 26. This note is evidently misdated, for the observation recorded in it is described in the paper of November 24, and in the following paragraph it is taken as evidence of the existence of an electrotonic state, a hypothesis which Faraday abandoned in his Bakerian Lecture, dated December 21. These two paragraphs belong somewhere in October, if the course of Faraday's thought can serve as a guide.

Volume I closes with this discovery and its elaboration. Faraday evidently felt that he was justified in expecting to succeed in obtaining other important results, for he published this work as his "First Series of Experimental Researches in Electricity" and began numbering the paragraphs consecutively. In the new folio volume of the diary which he opened on August 25, 1832, he also introduced this consecutive numbering of the paragraphs, which is continued until March, 1860.

Volume II opens with the record of many experiments made to show the identity of electricity from different sources. Most of the volume is taken up with the study of electrochemical decomposition, which led to the discovery of the laws of electrolysis. In October, 1835, Faraday left this subject for a while to study the phenomena presented by the induction of a circuit on itself. In this he had been anticipated by Joseph Henry. Before the close of the year he started work on electrostatic induction and the electric discharge, the result of which was his proof of the equality of the positive and negative charges and his discovery of specific inductive capacity. Volume II closes before the account of these researches is complete. He also for a while reverted to chemistry by the examination of the properties of fluorine.

With the work on electrostatic induction closes what Dr. Bence-Jones calls the first period of Faraday's experimental researches. He had for some time been weary and oppressed with giddiness and loss of memory, and shortly after this work was done he was forced to give up his studies altogether and rest. The famous discoveries of the magnetic rotation of the plane of polarized light and of diamagnetism, which were made after he returned to work, together with his speculations and philosophical views on the action of the medium in maintaining and determining the magnetic and electric fields will appear in the later volumes. The two now issued contain a large part of Faraday's experimental achievements.

It is interesting to notice that he tried (May 2, 1833) to obtain an effect on a beam of polarized light by passing it through an electrolyte which was transmitting a current, and also (May 6, 1833) by passing the beam through a piece of his borate of lead glass while it was in a strong electrostatic field (the Kerr effect), but with no positive results. He also (September 19, 1833) observed the same effect as that afterwards applied in the Groves' gas battery, without appreciating its meaning. Probably other hints of future discoveries could be found by a careful study of his records.

On a general view of these volumes one is struck with Faraday's astonishing industry. This is especially noticeable in the earlier years covered by the record. The number of chemical experiments made in one day while he was studying the compounds of chlorine, involving heating the mixtures and measuring the volumes of the gases produced from them, is amazing. Perhaps the most striking example is given

by the two days (October 28, November 4, 1831) in which he experimented on electromagnetic induction at Mr. Christie's with the great magnet of the Royal Society. On the first of these days he records no less than 27 separate experiments, and on the second 29, many of which were tried over and over. The number of tests made in one day with the electrolytic cells during his study of electrolysis in 1833 and 1834 is even more astonishing.

The notes exhibit, even better than his published work, the marvelous fertility of Faraday's mind. Every page, nay, nearly every paragraph contains a new thought, often unimportant, occasionally in error, but sometimes, when good fortune and inspiration combine, rising to the highest flights of the scientific imagination. From the best of these he constructed the great scientific poems of his published papers.

It also appears very plainly that a great deal of Faraday's work was done in his mind and is not recorded in his notebooks. To perceive this we need only compare the notes of his discovery of the induced current, with the beautifully ordered presentation of the subject in his first paper and in the Bakerian Lecture, or consider the notes on the phenomena of self-induction before, as Faraday says, he begins to see light. After he saw the light his experiments became more systematic and show how he worked when led by a guiding principle.

This publication constitutes a noble memorial to one of the greatest leaders in experimental science. Its value as a history of the way in which an honest, industrious and powerful mind operates on the facts of nature is inestimable. The thanks of the scientific world should be given to the managers of the Royal Institution and to any others who may have cooperated with them to make it possible.

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SOCIETIES AND MEETINGS

THE TEXAS ACADEMY OF SCIENCE

THE Texas Academy of Science held its annual meeting on November 11 and 12 in Houston, Texas. The number of papers appearing on the program was large and well distributed over the field of science. To bring together papers of like interests, five sections were in session throughout the meeting.

The section devoted to geological sciences was very popular. The notable papers included: "The Big Springs of Texas," by R. E. Ryan, of Houston; "The Salt Domes and Gulf Coast Oil Fields," an illustrated lecture by Marcus Hanna, of Houston; "Leaves of Geologic History from the Topography around Houston," Donald C. Barton. Among the twelve other papers, one by W. T. Carter, of the U. S. Soil Survey, on the "Relationship of Texas Soils to the Geological Formations" was considered as an outstanding piece of work. The Section of Zoological Sciences contained twelve papers. Several of these were abstracts of longer papers, which are to be printed. Of outstanding worth was the paper "The Fleas of Texas and their Economic Importance," by M. A. Stewart, of the Rice Institute, and of unique purport was the paper by Karl Bleyl, of the Sam Houston State Teachers College, in which he describes a new remedy for snake bite, which is a serum taken from the snake itself. The Botany Section was largely given over to papers on the technical side of investigation into the relationships of cotton. Several papers on regional ecology in Texas were given.

The Physical and Chemical Sciences gave papers ranging from the chemical contents of grapefruit, a study in vitamins; a description of a gigantic permanent magnet, and up to cosmic rays. L. M. Mott-Smith, and L. G. Howe, of Rice Institute, told of measuring this mysterious ray at the altitude of twelve thousand feet in an airplane. The Educational Section was given over to archeology; papers on the present social and financial conditions of the world; on mental operations accompanying emotions and including papers on the comparison of the Texas Academy of Science with other state academies, by S. W. Bilsing, representative to the American Association for the Advancement of Science, and one by Clyde T. Reed, College of Arts and Industries, on "Science Clubs and the Junior Academy." The annual lecture, given at the banquet, was "Genetical Views of the Origin of Life," by Edgar Altenberg. Just before Dr. Altenberg's lecture, H. Y. Benedict, president of the University of Texas and also of the academy, made an announcement relative to the new McDonald Observatory which is to be built by the university somewhere in the state of Texas. The last session was the annual business meeting. Seventy-five new members were taken in and five new fellows created. It was announced by F. B. Plummer, of the publication committee, that Volume XV of the *Transactions* would be ready for distribution in a few weeks, and P. L. Turner, representative of the Southwest Press, stated that "The Bird Life of Texas" had reached the point where subscriptions were asked for. The new officers are: E. N. Jones, Baylor University, *president;* F. B. Plummer, *executive vice-president;* H. A. Wilson, Rice Institute, *vice-president of Section 1;* Colonel M. L. Crimmins, *vice-president of Section 3;*

H. B. Parks, San Antonio, *secretary and treasurer*. S. W. Bilsing was continued as the representative to the American Association Council and given the authority to represent the Texas organization at the next annual meeting.

Following the business meeting, three papers were given by members who were unable to attend on the first day. The best of these was a paper by O. M. Ball, supplementing his recent publication "The Eocene Plants of Texas." This paper was illustrated by lantern slides showing newly discovered and described specimens. One of them was a beautiful leaf recently found in a quarry in East Texas and has been named Warneri after S. R. Warner, of Sam Houston State Teachers College, who collected the specimen. S. R. Warner is a member of the academy and was in the audience and heard for the first time of the importance of his discovery and the fact that the plant was named for him.

H. B. PARKS,
Secretary

THE OKLAHOMA ACADEMY OF SCIENCE

THE twenty-first annual meeting of the Oklahoma Academy of Science was held on November 25 and 26 at the University of Oklahoma, Norman. The meetings were divided into four sections and the number of papers presented in each section was as follows: Biology, 37; geology, 19; physical sciences, 22; social sciences, 29, making a total of 107.

The president's annual address was presented following the luncheon on Friday by Dr. Herbert Patterson, of the Oklahoma Agricultural and Mechanical College. The title of this address was "A Challenge to the Social Sciences." One hundred and fifty members and guests of the academy attended the annual banquet on Friday evening and Dr. Andrew Ellicott Douglass, professor of astronomy at the University of Arizona, gave an illustrated lecture entitled "Dating Prehistoric Ruins of the Southwest." Dr. W. B. Bizzell also gave a talk on "The Spirit of Adventure in Research." Dr. Douglass gave a second address at the general meeting of the academy on Saturday morning on the subject of "The Sun Spot's Cycle and the Cyclogram Method of Cycle Study."

One hundred and ninety members were registered and about 275 people attended the meetings.

The following officers were elected for 1933:

President, F. E. Knowles, Enid, Oklahoma.
Vice-president, Section A (Biology), Ralph D. Bird, University of Oklahoma, Norman, Oklahoma.
Vice-president, Section B (Geology), C. W. Tomlinson, Ardmore, Oklahoma.
Vice-president, Section C (Physical Sciences), Wm. V. N. Garretson, Stillwater, Oklahoma.
Vice-president, Section D (Social Science), O. D. Duncan, Stillwater, Oklahoma.
Assistant Secretary-Treasurer, Duane Roller, Norman, Oklahoma.

HORACE J. HARPER,
Secretary-Treasurer

STILLWATER, OKLAHOMA

SCIENTIFIC APPARATUS AND LABORATORY METHODS

AN APPARATUS FOR DETERMINING THE ABSORPTION OF CARBON DIOXIDE BY LEAVES UNDER NATURAL CONDITIONS

THE equipment described below was designed primarily for studies involving a large number of determinations of the photosynthetic activity of apple leaves under field conditions. The chief features are, first, a simple CO_2 absorption unit which can be made up of standard glassware and which is efficient, even though the air passes through the liquid at a rapid rate, and secondly, a light-weight, closely fitting leaf chamber made of cellophane, which is easily attached and held in place without cumbersome supports. The apparatus is essentially a simplification of that described by S. Kostytschew, K. Bazyrina and W. Tschesnokov,[1] and by Schandrel,[2] but involves less elaborate technique, so that a large number of determinations can be carried out at one time. An electric current is required to operate the pump.

The absorption unit is a modification of the Reiset tower used by Brown and Escombe[3] and consists of a glass tube, about 60 cm long and 3 cm in diameter, which is supported in an upright position. A glass Gooch crucible, with fused-in fritted glass disks, is attached to the lower end of the tower by means of thin-walled rubber tubing and serves to break the gas stream into minute bubbles. The size of the pores in the disks used was 100–120 microns, but finer grades of porosity down to 20–30 microns are available. The small end of the crucible is fitted with a rubber stopper, through which extends a short piece of glass tubing. A standard mercury filter with fused-in fritted glass plate may be used as a gas distributor instead of the Gooch crucible, but it is more expensive.

The upper end of the absorption tower is connected

[1] S. Kostytschew, K. Bazyrina and W. Tschesnokov, *Planta*, 5: 696–724, 1928.

[2] Hugo Schandrel, *Wiss. Archiv. für Landw. Abt. A Pflanzenbau*, 3: 529–560, 1930.

[3] H. T. Brown and F. Escombe, *Proc. Royal Soc.*, London, B 76: 29–111, 1905.

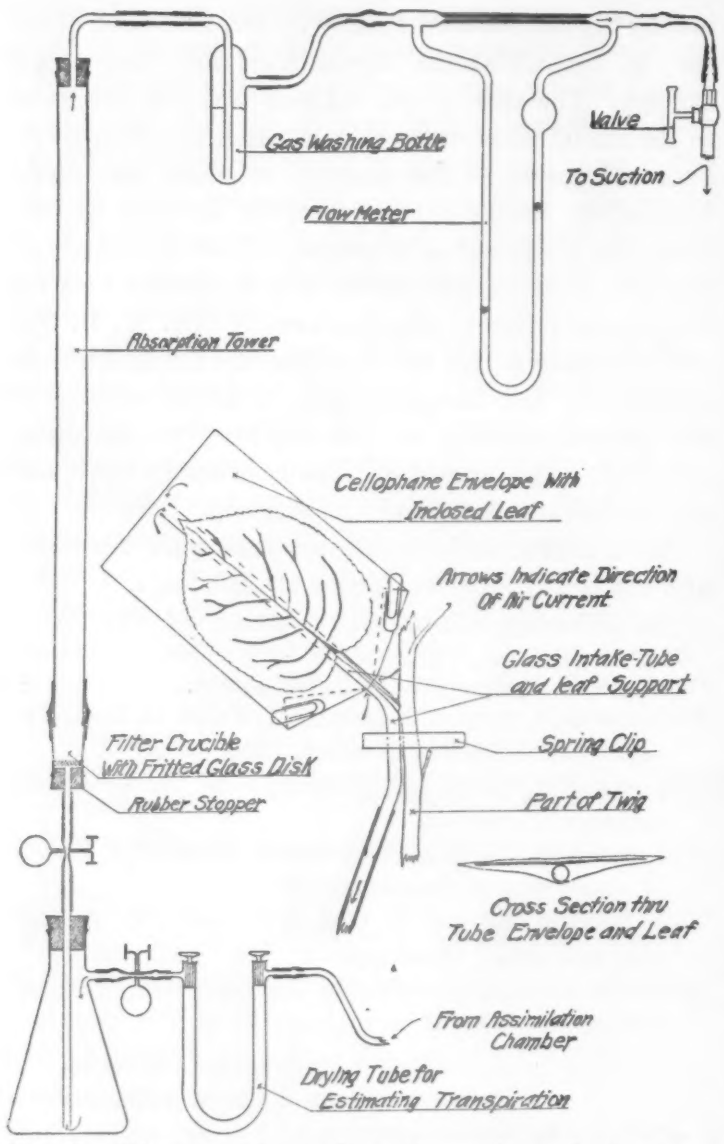

FIG. 1. Diagram of an absorption unit, and of an assimilation chamber.

by means of heavy rubber tubing to a flowmeter accurately calibrated with a Sargent wet test meter at different temperatures. The air passes through a dehydrating agent before it enters the flowmeter to avoid the accumulation of moisture in the capillary tube which has a bore of less than 1 mm and a length of 125 mm. An electric vacuum pump is used to pull the air through the system. By adjusting the sensitive gas valves, the mercury in the arms of the flowmeter can be kept at a definite level and the flow of air may thus be regulated to conform to a predetermined rate. The standard rate chosen for our preliminary tests was 100 liters per hour. The efficiency of the absorption unit is indicated by the fact that all carbon dioxide in the atmosphere is removed when passed through a column of 200 cc N/10 $Ba(OH)_2$ or KOH in a single tower at this relatively high rate, provided the solution remains sufficiently strong.

The reservoir containing the CO_2 absorbent consists of a 500 cc suction flask, fitted with a rubber stopper and a glass tube about 22 cm long. The glass tube touches the bottom of the flask, and its upper end, which extends above the stopper about 5 cm, is provided with a short piece of rubber tubing and a pinch-cock. A similar connection is found on the side arm of the suction flask.

A definite amount, usually 200 cc, of N/10 $Ba(OH)_2$ or N/10 KOH is allowed to flow from the protected stock bottle through a connected burette directly into the flask. To charge the flasks with the standard solution requires only a few minutes, after which all the pinch-cocks remain closed until the determinations begin. A large number of flasks may be filled in the laboratory to serve for many determinations in the field.

The leaf chamber, adopted as a standard after experimenting with many other types, consists of an envelope made from heavy-weight, moisture-proof cellophane. A special moisture proof paste must be used to seal the overlapping edges. The size may vary with the leaf to be studied. The envelope is slipped over a leaf which has previously been provided with a combination support and air intake. This consists of a glass tube which is bent as indicated in the diagram. It is held firmly in position against the stem by means of a spring clip so that the long arm passes on the under side of the leaf and supports it at an angle of about 30 degrees from the horizontal. A heavy-walled rubber tube attached to the glass support connects it with the side arm of the suction flask.

After the assimilation chamber is in place, the flaps on the open edge near the base of the leaf are bent back and held in place on the under side by means of paper clips. The corners of the envelope may also be folded back to reduce the size of the chamber to a minimum. The cross-section shows how the envelope fits about the leaf so as to avoid "dead air spaces" which might possibly interfere with the free supply of fresh air and carbon dioxide. The glass tube keeps the cellophane a few millimeters away from the under side of the leaf where the stomates are chiefly found on material we have used. The envelope with the enclosed leaf is easily held in place and may be adjusted to any plane, using the glass intake-support tube as an axis. It is thus possible to expose the leaf at a right angle to the sun's rays if desired. With some modification, the support and cellophane chamber can be used for two or more leaves or even for a whorl of leaves on a spur.

The supply of fresh air enters through the small opening which is left around the glass tube and the petiole. A thermometer may be inserted in this opening to record the temperature within the chamber. After passing over the leaf, the air is drawn to the absorption unit through the glass tube at the upper edge of the envelope. The single arm of the intake

tube may be replaced by a Y-tube or a T-tube so that the air is withdrawn from the corners of the envelope, thus tending toward a somewhat better circulation of air over all parts of the leaf.

In spite of the rapid movement of air through the chamber (100 L. an hour), the temperature of the chamber when exposed to the direct sun will be from 6 to 10 degrees C. higher than the surrounding air. Condensation of the water vapor transpired by the enclosed leaf may occur on the relatively cool lower and shaded side of the envelope, but since little or no moisture is lost through the upper surface of the leaf, there is practically no accumulation of water on the corresponding exposure of the envelope. Excessively high and injurious temperatures, due to concentration of the heat rays in different parts of the leaf, are thus avoided. After several hours' use the cellophane becomes wavy and the moisture-proof coating may disintegrate, but this does not seem to interfere seriously with the transmission of light, nor does it have any noticeable detrimental influence on leaf activity. The wet cellophane becomes flaccid, but resumes its original stiffness when air dried.

The water transpired by the leaf in the chamber may be estimated by having the air pass through a dehydrating agent before it reaches the absorption tower. The weight of moisture adhering to the envelope must be added.

After all parts of the apparatus are in place, the stop-cocks on the suction flask are opened. The air is pulled through the system at the standard rate of 100 L. per hour, regardless of the size of the leaf. This should insure an ample supply of air containing "normal" amounts of CO_2, and it may actually provide the leaf with more CO_2 than it would have access to in relatively still air.

In our experiments, six to eight complete units, as described above, are attached to the same suction tank and are operated at one time. The air moving through each unit, of course, is governed by a flowmeter for each tower. All but two units are used to measure the carbon dioxide absorbed after the air has passed the leaf in the assimilating chamber. The remaining two units are used for control of the amount of carbon dioxide absorbed during the operations of filling the flask and titrating the solution, and also to determine the amount of carbon dioxide absorbed from an equal volume of "normal" air obtained within a few feet and at the same level as that which is passed over the enclosed leaves. The air used in these controls is made to pass through a cellophane envelope which is identical with that used on the leaves, so that the temperature of the gas entering the system is the same in all cases.

The running time has usually varied from one half to three hours, although the apparatus may be operated for longer periods by using a stronger solution for absorption. After each run, the liquid is allowed to flow back through the filter into the reservoir flask and the absorption tower is repeatedly rinsed with small amounts of distilled water until about 150 cc has been used in each case. Where the precipitate of barium carbonate is very heavy, suction may have to be applied to the flask, but this is unnecessary for periods not longer than one hour, or when potassium hydroxide is used as the absorbent. After the tower is thoroughly cleaned of adhering alkali solution, the flask is disconnected from the system and the pinch-cocks are closed. Flasks contained fresh solution are put in place, after which the suction may be started for another determination.

The amount of carbon dioxide absorbed during the operating time is determined by titrating an aliquot of the solution in the flask, after adding barium chloride. The error introduced by the absorption of CO_2 during the operations of charging the flasks and titrating the unused alkali has been determined to be negligible in our experiments. The great dilution of the hydroxide solution caused by the use of liberal quantities of distilled water in rinsing minimizes the amount of carbon dioxide absorbed during titration. Where the flow is accurately regulated, the controls give identical results. The activity of the leaf with respect to the utilization or production of carbon dioxide is determined by the difference between the amounts absorbed by these control units and by the other units.

In agreement with Lundegardh, and others[4] the amount of carbon dioxide in 100 L. of "normal" air has been found by the use of the above apparatus to vary from as low as 38 mg to as high as 70 mg in a warm, unventilated greenhouse containing about 100 young vigorous apple trees growing in tubs. The former concentrations are more frequent on a clear mild day in a ventilated greenhouse during the morning hours, while the higher concentrations occurred at night. There may be appreciable variation from one hour period to the next, so that controls are essential for every determination.

The apparatus has been used to study the efficiency of apple leaves on plants grown under different conditions of nutrition. In some of our experiments, as high as 25 per cent. of the carbon dioxide contained in the "normal" atmosphere was removed by passing over a single leaf, but as a rule the amount removed was less than 10 per cent. The amount of carbon

[4] Henrik Lundegardh, "Environment and Plant Development." Trans. Eric Ashby. Edward Arnold and Company, London. 1931. p. 264.

dioxide absorbed during one-hour periods per 100 sq cm of healthy leaf surface exposed to the light varied from less than 1 mg to as high as 25 mg, with 2 to 10 mg the most frequent rate during the morning hours. In a few cases during daylight hours in the forenoon, the leaves actually increased rather than reduced the carbon dioxide content of the air. The respiratory rate is determined during the day by excluding light from leaves whose photosynthetic activity was established during the preceding hour, or by making determinations during the night.

In general, our preliminary results, obtained with the apparatus described, conform with those recorded by the Russian authors previously referred to, and they indicate that wide fluctuations in the activity of a given leaf from hour to hour and from day to day are to be expected, even though the temperature and other environmental factors are the same in successive periods. Nevertheless, a relatively active leaf seems to hold its rank compared to others under many varying conditions. The apparatus described should therefore be useful for many studies involving a knowledge of the leaf efficiency as influenced by a number of conditions or treatments.

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SPECIAL ARTICLES

THE FUNCTION OF THE ADRENAL CORTICAL HORMONE AND THE CAUSE OF DEATH FROM ADRENAL INSUFFICIENCY[1]

THE functional significance of the adrenal cortex is unknown; practically all investigators of the problem agree upon this point. Various tentative hypotheses have been advanced to account for the function of these glands, but none of these hypotheses, or all of them taken together, have materially advanced the problem of cortical function.

We are of the opinion that data now in our possession, merely a brief outline of which will be presented here, explain in large measure the function of the adrenal cortex and the cause of death from adrenal insufficiency. The nature of the data is such that it is highly important to have in mind a clear picture of the type of experimental animal employed.

Bilaterally adrenalectomized dogs are used: they have well-healed wounds, are perfectly normal healthy animals at their peak weight. Any one viewing these dogs would be quite unable to distinguish them by appearance or behavior from control unoperated individuals. From the day of gland removal they are injected daily with adequate maintenance doses of the cortical hormone until ready for use. Some of the animals have been bilaterally adrenalectomized for nearly two years, others for lesser periods. In all cases, however, they were permitted to develop severe symptoms of insufficiency by withdrawal of extract, and then revived and returned to normal health by adequate injections of hormone. This is the routine procedure in the laboratory before any adrenalectomized dog is regarded as a fit subject for experimentation. Several of the older animals have passed through this routine eight to ten times. Our adrenalectomized dogs are, by all anatomical and physiological criteria employed, perfectly normal healthy animals, except that they lack adrenal glands. We reiterate and emphasize this point purposely. When an experiment starts, the cortical hormone is withheld and the animal allowed to become prostrate from insufficiency. Adequate doses of the hormone are then given and the animal returns to normal.

Study of such animals reveals some new and interesting data which, for the sake of brevity and clarity of presentation, will be given as bald statements. The more important points supporting these statements will be discussed more in detail later.

(1) The function of the adrenal cortical hormone is the regulation and maintenance of a normal circulating volume of fluid within the vascular system. In the absence of the hormone, fluid is continually lost from the circulation presumably by transudation through the capillary walls, with the result that the adrenalectomized animal is unable to maintain his normal blood volume, and eventually dies from circulatory collapse due to insufficiency of circulating fluid.

(2) Accompanying the progressive decrease in blood volume is a progressive fall of blood pressure to the death level. The decline in arterial pressure is apparently a direct result of the decreased volume of circulating fluid.

(3) The decrease in blood volume and blood pressure are not terminal phenomena, but first appear within twenty-four to seventy-two hours after discontinuing hormone injections and before active symptoms of insufficiency appear. Both volume and pressure steadily decline to the death point, which may not occur until eight to twelve days later.

[1] The expenses of this investigation, including the cost of enlarging this issue of SCIENCE to make early publication possible, have been defrayed by a grant from the Josiah Macy Foundation of New York.

(4) The manifestations and symptoms of adrenal insufficiency parallel in remarkable fashion the decline in blood pressure.

(5) Hemoconcentration, increased blood viscosity and the marked slowing of the circulation which invariably appears, are directly correlated with and chiefly dependent upon the decline in plasma volume and blood pressure.

(6) The heart rate varies inversely as the blood pressure, and the change in rate appears to be due to the progressively diminishing venous return to the right heart, and the effort of the heart to compensate for the greatly decreased quantity of fluid in circulation.

(7) The blood-urea and non-protein nitrogen also vary inversely as the blood pressure. The decreased renal function, so evident during adrenal insufficiency, we attribute to the changes in circulation previously mentioned, *i.e.*, diminished blood volume, decreased pressure, and presumably, therefore, to decreased filtration pressure and blood flow in the kidney.

(8) The increased viscosity of the blood is due to loss of fluid and increase of corpuscles per unit volume, and to the increase in plasma proteins due to hemoconcentration.

(9) Adrenalectomized animals, in the absence of the cortical hormone, are apparently unable to draw fluid back into the blood stream through the capillary walls. The accepted view that the osmotic power of the blood colloids is the chief factor involved in compensation needs further investigation. The blood colloids are proportionately increased in adrenal insufficiency, yet the animal does not dilute or compensate in face of a declining blood volume and arterial pressure.

(10) Following administration of adequate amounts of cortical hormone to prostrate adrenalectomized dogs, the blood volume, blood pressure and blood constituents all return to normal. The animal is able to dilute his blood and build up a normal blood volume, and all symptoms of adrenal insufficiency disappear.

(11) It is our opinion that all the manifestations, symptoms and physiological peculiarities, which have been described as occurring in adrenalectomized animals (see table on insufficiency), are merely results of a progressively failing circulation due to decreasing volume of circulating fluid, in an animal which is unable to compensate (as do normal animals) for its low blood volume and blood pressure by dilution.

(12) The striking similarity between the symptoms of adrenal insufficiency and those of traumatic or secondary shock, as reported in the literature for man, is too obvious to be ignored. The cardinal features of traumatic shock are likewise the cardinal features of adrenal insufficiency—*viz.*, depleted blood and plasma volume, lowered arterial pressure, hemoconcentration and inability to dilute the blood (uncompensated human cases). The really essential point in secondary shock is failure of the blood-diluting mechanism and loss of power to increase the blood volume. This is also the primary cause of the symptoms of adrenal insufficiency.

These statements require supporting evidence of an unequivocal nature. We believe that our data are sufficient to establish these contentions, and the main points will be briefly outlined here.

BLOOD VOLUME

Fig. 1 shows the blood volume, hemoglobin, hematocrit and urea nitrogen changes in one of our experimental animals. The plasma volume of adrenalectomized dogs is invariably low. Losses of 40 to 50 per cent. of the plasma frequently occur. However, it is our opinion that the "vital-red" method of determining blood volume does not really gauge the extent of the plasma loss in an animal coming into insufficiency. The method is as good as any other now in use, but circulatory conditions are so peculiar in adrenal insufficiency that any of the present indirect methods for determining blood volume would be similarly inadequate.

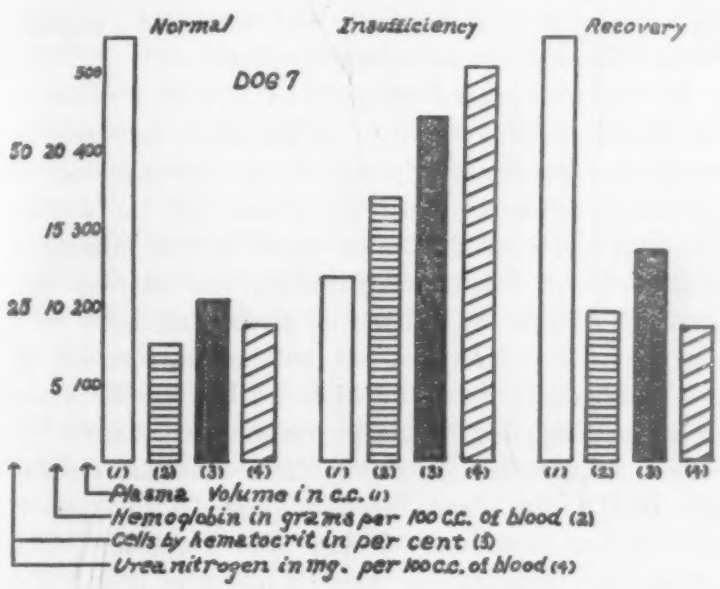
Normal
Insufficiency
Recovery
DOG 7
50 20 400
15 300
25 10 200
5 100
(1) (2) (3) (4) (1) (2) (3) (4) (1) (2) (3) (4)
Plasma Volume in c.c. (1)
Hemoglobin in grams per 100 c.c. of blood (2)
Cells by hematocrit in per cent (3)
Urea nitrogen in mg. per 100 c.c. of blood (4)

FIG. 1. The changes in plasma volume, hemoglobin, cells by hematocrit, and urea nitrogen in an adrenalectomized dog followed through a cycle of insufficiency. This animal had been adrenalectomized ten months previous and maintained in normal condition by adequate doses of cortical hormone.

We have strong evidence for the belief that our animals presenting volume readings indicating a plasma loss of 40 to 50 per cent. have really lost greater quantities. Data obtained by employing the "washout" method for blood volume determination reveal that the adrenalectomized dog loses 40–50 per cent. of his total blood volume within the first two or three days after withdrawal of hormone and before

any evident symptoms of insufficiency appear. The animal eats normally, he is active and vigorous and to all appearances normal, yet his blood volume is greatly depleted. Accompanying this early diminution in volume is a small increase in blood urea, and a decline in arterial pressure of approximately 20–25 mm Hg.

The "washout" method of blood volume determination is apparently more reliable than the "vital red" method in so far as adrenal insufficiency is concerned. Unfortunately it necessitates sacrificing the animal. We do not yet know how low the blood volume actually sinks before death occurs. We are now investigating this point. But taking the "vital red" data as it stands, it is clear that the blood volume decreases to a low figure in insufficiency and returns to a normal level following extract administration.

In a normal animal with adrenal glands, a decrease in plasma volume of 40 to 50 per cent. may not be fatal or even necessarily lead to the development of serious symptoms. Such an animal has the ability to compensate or dilute his blood in the face of a falling blood volume or pressure, and thereby can rapidly restore the volume of circulating fluid to a normal level. However, the outstanding feature of the adrenalectomized animal is its loss of the blood compensating and diluting mechanism. Losses of blood, which would be negligible in a normal animal, are fatal to the adrenalectomized dog. Both types of animal are continually losing fluid from the blood stream by transudation through the capillaries. But whereas the normal dog continually dilutes and restores his blood volume, the adrenalectomized dog is unable to do so, and his blood fluids drain into the tissues and are lost from circulation. This point is discussed more in detail in the following section.

Compensation or Dilution Following Hemorrhage, etc.

Further evidence supporting the contention that in adrenalectomized animals the blood volume progressively decreases to a level incompatible with life is furnished by bleeding experiments. Following hemorrhage, the normal animal with intact adrenal glands rapidly dilutes its blood by drawing fluid back into the blood stream to compensate for the decreased plasma volume. This power of compensation is remarkable, as any one will attest who has studied the problem. Normal dogs, weighing 10 to 12 kilograms, can withstand the loss of 40 per cent. of their total blood volume, or as much as 350 to 400 cc at one time, and within a period of a few hours or less, dilute to the extent of regaining their original volume. This compensation is due to withdrawal of water from the tissues. We have repeatedly removed 40 per cent. of the blood volume of normal unanesthetized dogs and cats, and observed that within three or four hours they were perfectly normal. Such observations are, of course, familiar to any student of hemorrhage.

The power of normal animals to compensate by dilution for lowering of blood volume is regarded as due to such reduction of blood pressure in the capillaries that the filtration pressure from within them no longer offsets the greater osmotic pressure of the plasma colloids as compared with the lymph, and consequently fluid passes into the blood stream. This mechanism of compensation, however, is probably not the sole factor involved, for we have evidence that the adrenal cortical hormone is vitally concerned in the phenomenon of blood dilution. In fact, our observations show that in the absence of the cortical hormone the animal lacks the ability to dilute its blood, even after slight or negligible blood loss. Following hormone administration, dilution again occurs.

Adrenalectomized dogs with well-healed wounds, and kept in perfectly normal condition by maintenance doses of extract, dilute their blood after hemorrhage, just as do normal unoperated animals. If extract is withheld for two or three days until the hormone content of the blood diminishes, the animals remain normal in all respects, except for decreased blood volume and pressure. They are vigorous and eat heartily. However, if small amounts of blood are removed, quantities which would be quite negligible to an animal with intact adrenals, an interesting phenomenon occurs. The blood pressure sinks to a very low level, where it remains unchanged for hours. No dilution occurs, and unless the cortical hormone is given, the pressure starts to decline further, and the animals die presenting all the classical symptoms of adrenal insufficiency. Following injection of the hormone, dilution promptly occurs, the blood pressure rises to normal and the animal returns to a normal condition, as evidenced by the changes in hemoglobin, hematocrit and plasma volume. We will cite one typical example.

An adrenalectomized dog (operated four months previously), weighing 10 kg and maintained in normal health by hormone, was taken off extract for several days. The dog remained normal in every respect; and the day he was bled he had eaten his full ration of 800 grams of kennel ration. His blood pressure had, however, declined from the normal of 106 mm Hg to 85 mm Hg. This decrease did not affect his vigor. A total of 40 cc of blood was withdrawn from the femoral artery over a period of one hour—an amount representing 5 per cent. of his normal blood volume. The animal's blood pressure fell

from 85 mm Hg to 42 mm of Hg and the dog exhibited signs of prostration. He was able to walk back to his cage where he remained in a stuporous condition for 7 hours. At the end of this time his blood pressure remained unchanged at 42 mm of Hg. A few hours later it began to decline and an injection of extract was deemed necessary. Intravenous injection of an adequate amount of the hormone was given. Four hours later the blood pressure had risen to 60 mm and within 12 hours the pressure was 80 mm Hg. The dog was eating, and ran about the laboratory. Twenty-four hours after injection the pressure stood at 100 mm of Hg. Compensation or dilution had occurred, and the animal was again perfectly normal. Dilution never occurs in such animals, and death results, unless the hormone is injected.

In contrast to the type of experiment just mentioned, we can cite numerous experiments on bleeding normal dogs, both from our own experience and that of others, where large quantities of blood, 300 to 350 cc, are drawn at one time. The animals do not exhibit distress, but compensate by dilution extremely rapidly. The evidence seems clear that adrenalectomized animals are unable to dilute their blood, and can do so only when the cortical hormone is supplied.

The experiments upon hemorrhage also lend additional weight to our data on lowered blood volume in the adrenalectomized animal. Normal dogs of 10 to 12 kilograms weight can withstand relatively huge losses of blood without evident symptoms. A similar sized adrenalectomized dog, apparently enjoying equally good health, can not tolerate a loss as trivial as 50 to 75 cc, even when it is withdrawn over a period of an hour or two, without passing into a serious shock-like condition comparable to adrenal insufficiency prostration. The small quantity of blood removed from an adrenalectomized dog is of no significance to a normal animal possessing a diluting mechanism, but the loss of 50 to 75 cc by an animal which by all criteria such as vigor, activity and appetite is normal but which lacks power of compensation, and whose blood volume is already lowered, is fatal.

Another type of experiment showing the relation of the cortical hormone to the diluting mechanism is as follows: When the adrenalectomized dog, in severe insufficiency with a greatly lowered blood volume, a blood pressure of 40 mm Hg and a high blood urea, is injected intraperitoneally with 500 cc of normal saline, nothing happens and the animal dies. The individual is unable to tap the reservoirs of fluid because it can not dilute. However, if to such an injected dog hormone is administered, or fluid given by mouth, he revives in remarkable fashion. The blood pressure may rise 10 mm of Hg per hour for two or three hours until the pressure has risen to 70 to 80 mm Hg and the animal is restored to normal so far as vigor and appetite are concerned. The hormone enables the animal to utilize the injected reservoir of fluid in the body cavity, and dilution occurs very rapidly—more so than when such animals are not given fluids intraperitoneally.

Blood Pressure

The importance of close observation of the blood pressure in adrenalectomized animals can not be overemphasized. The great hindrance has been the difficulty of making repeated determinations upon the same animal. The repeated daily arterial cannulation, necessary as a preliminary to the use of the mercury manometer on the unanesthetized adrenalectomized dog, is a technical impossibility. With the exception of Rogoff, who used the carotid loop, no other method has been employed. When consideration is given to the extreme sensitivity of adrenalectomized animals to anesthetics of any kind, to trauma or slight blood loss, it is easy to appreciate the difficulty of any prolonged study of blood pressure in such an individual over a period of several weeks or months.

We are using the direct intra-arterial method of Dameshek and Loman, which is extremely simple, highly accurate, and which makes it possible to determine the arterial pressure of an unanesthetized dog any number of times desired. The device has been repeatedly checked against the arterial cannulation method at high, low and normal pressures, using the two methods simultaneously in the same animal. The readings in mm of Hg are essentially the same in both instruments.

Two further points should be mentioned. Our animals are table trained especially for blood pressure work, and the pressures are determined directly in the femoral artery. The cortical hormone *per se* has no effect upon blood pressures. Slow or rapid intravenous injections of 30 to 40 cc of highly potent hormone does not raise the pressure in either the normal or adrenalectomized dog, except for a slight evanescent rise due to the traces of adrenalin present.

The resting arterial pressure of adrenalectomized dogs on maintenance doses of hormone is perfectly normal. It varies in different individuals from 100 to 115 mm Hg. After cessation of extract injections, the pressure progressively sinks day by day until the death level is reached. Fig. 2 shows the typical changes in arterial pressure in one of our cases. The symptoms of adrenal insufficiency parallel the decline in pressure. When the pressure is at a low level, in many cases as low as 45 to 30 mm of Hg, the animals exhibit severe symptoms and must be injected

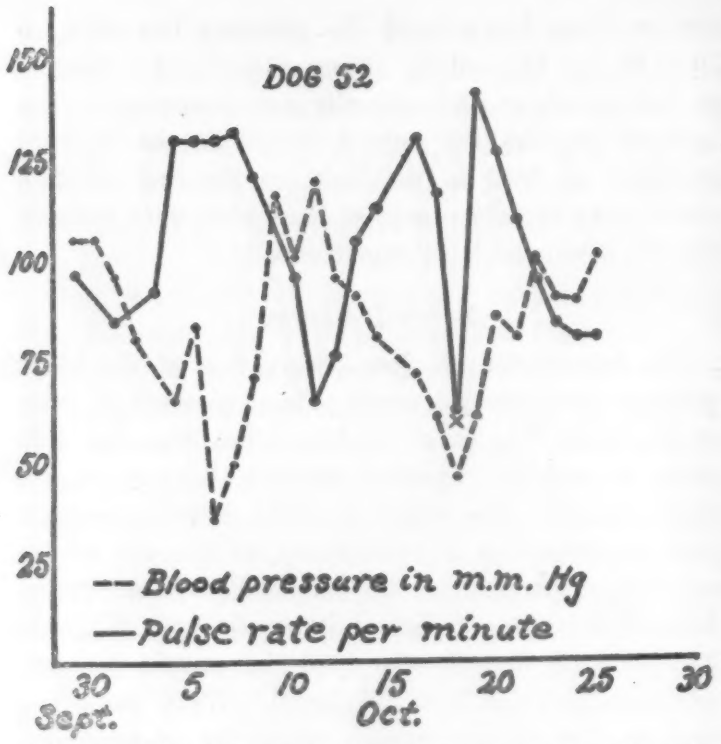

FIG. 2. The changes in blood pressure and pulse rate in an adrenalectomized dog followed through two cycles of insufficiency and recovery on extract. The significance of X is explained in the text.

with cortical hormone in order to prevent the pressure from sinking to the death level. Following injection, the pressure rises steadily and within 72 hours or less has attained the normal level and all symptoms disappear.

The decline in arterial pressure is one of the first departures from normal the animal off extract exhibits. Several days before the animal stops eating the pressure has fallen to 60 to 70 mm Hg. It is remarkable how active and normal such dogs appear with arterial pressures as low as they are. An arterial pressure of 60 to 70 mm of Hg is in general insufficient to produce noticeable symptoms in our dogs. It is only when the pressure sinks to below 60 mm that symptoms appear. We have observed several dogs, with arterial pressures as low as 36 to 39 mm of Hg, which were able to hop off the table and trot back to their cages. They were a bit wobbly on their feet, it is true, but nevertheless they were up and about.

The heart rate in general varies inversely as the blood pressure. When the pressure is normal, the heart is slow and steady. However, when the pressure starts to decline the heart rate speeds up and maintains a rapid rate so long as the pressure remains low. With a return to normal pressure, the heart rate decreases to normal. Fig. 2 illustrates these points. Some of our dogs show a precipitous fall in heart rate a few hours before death occurs. This is shown at X in Fig. 2. Following extract injection, the heart rate of such animals increases to a high figure and then declines to normal as the pressure returns to normal level.

Since the fall in blood pressure in the adrenalectomized dog is dependent upon the decline in plasma volume, the rise in pressure after extract administration depends upon the rapidity with which fluid is drawn back into the circulation and the blood volume increased. We have observed rises in arterial pressure of 10 mm of Hg per hour for the first two or three hours after injection, though generally the rise is around 5 mm of Hg per hour. When rapid dilution has occurred and the pressure stands at 65 to 70 mm of Hg, the rate of increase slows up. In all cases the pressure attains its normal level along with a normal blood volume by the end of 72 to 80 hours. The effect of the cortical hormone upon blood pressure is indirect, it raises the pressure by increasing the plasma volume, *i.e.*, the amount of fluid in circulation, and in no other way, so far as we have been able to determine.

BLOOD VISCOSITY

The blood of adrenalectomized animals becomes increasingly viscous. Data obtained from two experimental dogs are shown in Fig. 3. The increased viscosity is attributable in large part to (1) the increase of corpuscles per unit volume due to decreasing plasma volume, and (2) increase in plasma proteins due to hemoconcentration.

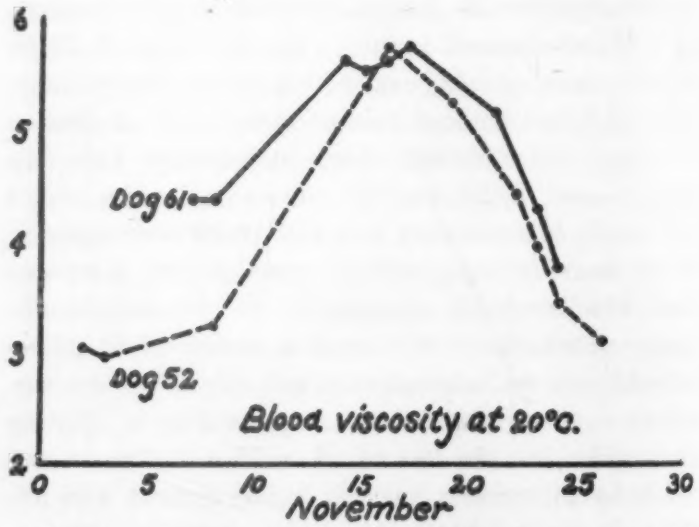

FIG. 3. Changes in blood viscosity of two dogs followed through a cycle of adrenal insufficiency and recovery after extract administration. The peak of the curve coincides with the point where extract was injected and when symptoms were most severe.

BLOOD UREA AND NON-PROTEIN NITROGEN

One of the earliest changes from normality in the adrenalectomized dog deprived of extract is a rise in blood urea and non-protein nitrogen. This rise occurs

simultaneously with the fall in arterial pressure, and an inverse ratio exists between the two, as a glance at Fig. 4 will show. When the blood pressure is normal,

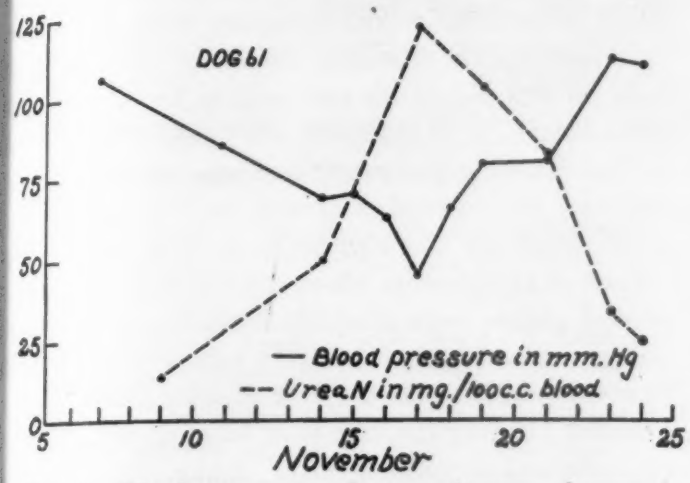

FIG. 4. Blood pressure and urea nitrogen changes in an adrenalectomized dog followed through a cycle of insufficiency and recovery on extract treatment.

the blood urea is low and at the normal level. When the pressure falls the urea rises and attains its peak when the arterial pressure is at a low level. Following extract injections the blood pressure slowly rises along with the blood volume, and the urea and non-protein nitrogen slowly falls.

Daily observation of blood urea and blood pressure reveals that, in general, the pressure starts to decline at approximately the same time as a detectable elevation of urea occurs, thus indicating that the rise in urea and non-protein nitrogen depends upon the falling pressure. However, we have observed several animals which showed a slight elevation of blood urea before the blood pressure had changed significantly. In such cases it seems likely that the blood flow through the kidneys is lessening as a result of a decreasing volume of circulating fluid.

When the animal exhibiting marked symptoms of adrenal insufficiency, with a very low arterial pressure, and a high blood urea, is given adequate injections of cortical hormone, the blood pressure invariably rises to the normal level before the blood urea sinks to its normal level. There is a lag of 24 to 48 hours after the normal pressure has been attained before the urea reaches the normal level. This lag is to be expected when we consider that the rise in blood pressure means that the animal is building up a normal volume of circulating fluid. The fall in urea occurs when the kidney function is resumed with consequent outpouring of urea.

The fact that the elevation of blood urea and non-protein nitrogen turns out to be dependent upon diminished blood flow through the kidney does not detract from the importance of the urea as a means of biological assay of the adrenal cortical hormone. The writers have long recognized that this method of assay is based upon a secondary phenomenon of adrenal insufficiency, namely, lowered renal activity. However, since the changes in blood urea are so easy to follow and so simple to quantitate, this method of assay retains its value.

ADRENAL INSUFFICIENCY AND TRAUMATIC SHOCK

It is obvious that the conditions existing in adrenal insufficiency in animals are strikingly similar to those reported as occurring in traumatic or secondary shock in man. During the war detailed studies of traumatic shock were made on large numbers of individuals. In the following table we have listed the chief findings in adrenal insufficiency and traumatic shock and have arranged them for comparison. The signs and symptoms of the two conditions are very similar.

TABLE 1

CONDITIONS EXISTING IN ADRENAL INSUFFICIENCY (ANIMALS) AND TRAUMATIC SHOCK (MAN)

1. Blood volume	Decreased
2. Blood pressure	Decreased
3. Hemoglobin	Increased
4. Hematocrit	Increased
5. Red cell count	Increased
6. Venous pressure	Decreased
7. Rate blood flow	Decreased
8. Blood viscosity	Increased
9. Hemoconcentration	Increased
10. Cardiac output	Decreased
11. Venous return to R. heart	Decreased
12. Heart rate	Increased
13. Heart condition	Normal apparently
14. Weak, fast pulse	Present
15. Vaso constriction	Present
16. Ability to dilute	Lacking
17. Blood non-protein nitrogen and urea	Increased
18. Alkali reserve	Decreased
19. Basal metabolism	Decreased
20. Blood sugar	Decreased in adrenal insufficiency Normal or slightly above in traumatic shock
21. Body temperature	Decreased
22. Use vaso constrictor drugs	Ineffective
23. Effect forcing fluids	Beneficial
24. Vaso motor center	Normal apparently
25. Sensitivity to painful stimuli	Decreased
26. Sensitivity to cold	Increased
27. Sensitivity to anesthetics	Increased
28. Sensitivity to histamine	Increased in adrenal insufficiency, action unknown in shock
29. Sensitivity to infections and toxins	Increased
30. Urine volume	Decreased
31. Sensitivity to hemorrhage	Increased
32. Sensitivity to trauma and operation	Increased

Blood sugar in insufficiency is generally lowered, whereas in traumatic shock it is either at the normal

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level or else slightly above. However, there is generally considerable laceration and tearing of tissue, together with blood loss in traumatic shock. These conditions may tend to raise blood sugar, for Aub has reported high blood sugars in shocked cats whose thigh muscles had been crushed. The cause of the low blood sugar in adrenal insufficiency will be discussed in a later paper.

It is the opinion of the writers that, since the essentials of adrenal insufficiency in experimental animals are very similar with those of traumatic shock in man, the two syndromes may possibly have a common origin —namely, some derangement of the adrenal cortex and deficiency of its hormone. In the adrenalectomized animal the glands have been extirpated, while in the shocked man they are still present, but the question arises—are the glands fully functional? If one may judge from the symptoms of traumatic shock the cortex would appear to be non-functional. In traumatic shock the individual is either unable to dilute his blood and increase his depleted blood volume (uncompensated cases) or else is able to partially do so, but only slowly (partially compensated cases) and must be aided by injecting fluids to increase the volume of fluid in circulation. The same condition exists in adrenal insufficiency in experimental animals. The animal lacks ability to dilute its blood in the face of a falling plasma volume and arterial pressure, and, in the absence of the cortical hormone, invariably dies. For some time the writers have been tempted on theoretical grounds alone to suggest that the secret of traumatic shock may possibly lie in the adrenal cortex, and that the cortical hormone may be found to be of benefit in controlling this syndrome in man.

Recently we have performed a set of experiments to test the relation between failure of the cortex and traumatic shock. The results are highly suggestive. Adrenalectomized dogs on maintenance doses of extract were used. The extract injections were discontinued for two days to permit the concentration of hormone in the animals to diminish. The dogs were still in perfectly normal condition and indistinguishable from normal dogs. They were lightly anesthetized with ether, the blood pressure determined and the testicles crushed in a vise by gradually increasing pressure. The recovery from ether was rapid and the animals were up and about within thirty minutes. The blood pressure was followed closely. One typical case will be cited. The arterial pressure dropped from 112 mm of Hg to 79 mm of Hg immediately after injury. One hour later the pressure stood at 54 mm of Hg. Two hours later it had risen to 67 mm of Hg. From this time on, however, the pressure slowly declined until at the end of eight hours it was 46 mm of Hg and the animal was prostrate and in profound shock. No dilution or compensation had occurred except the evanescent rise during the first two hours. The dog was in such desperate straits that it was injected intravenously with adequate doses of extract. Two hours after injection the blood pressure rose from 46 mm Hg to 68 mm, and at the end of four hours from time of injection, the pressure was 74 mm of Hg. The dog was running about, was bright, energetic and ate his food in normal fashion. At the end of 48 hours the dog's pressure was 112 mm of Hg.

Control experiments where normal dogs with intact adrenal glands were similarly treated gave results as follows: Blood pressure before injury 135 mm Hg. (Animal under ether). Immediately after injury pressure 112 mm Hg, one hour later pressure 92 mm Hg. Animal ate meat eagerly. Two hours later pressure 92 mm, animal normal. Three hours after injury pressure 109 mm of Hg. The animal appeared perfectly normal at all times during the experiment.

A second set of somewhat similar experiments has been performed, in which profound surgical shock was induced in normal dogs by double adrenalectomy at one sitting. Immediately following completion of the operation, the blood pressure was normal. After twelve hours, the degree of shock was such that the animals appeared moribund. Blood pressure 35 to 39 mm of Hg, heart rate 200, femoral pulse so feeble it could barely be felt. The animals were conscious but apathetic and quite insensitive to pain. The blood-diluting mechanism had completely broken down and compensation was lacking. Intravenous injections of adequate doses of the cortical hormone restored these profoundly shocked animals to normal life and vigor within 48 to 72 hours. These animals are alive and well at the present time, some three weeks after operation. Dogs similarly "shocked" and not injected with hormone invariably die within 48 hours.

These experiments lend considerable weight to our suggestion that the signs and symptoms of adrenal insufficiency, and of traumatic or secondary shock, are possibly due to one and the same thing, *i.e.*, failure of the blood volume and blood-diluting regulator mechanism, the adrenal cortex. The idea that the adrenal cortical hormone might prove of benefit in the treatment of human traumatic shock is advanced merely as a suggestion. Adequate proof can only come through clinical trial.

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